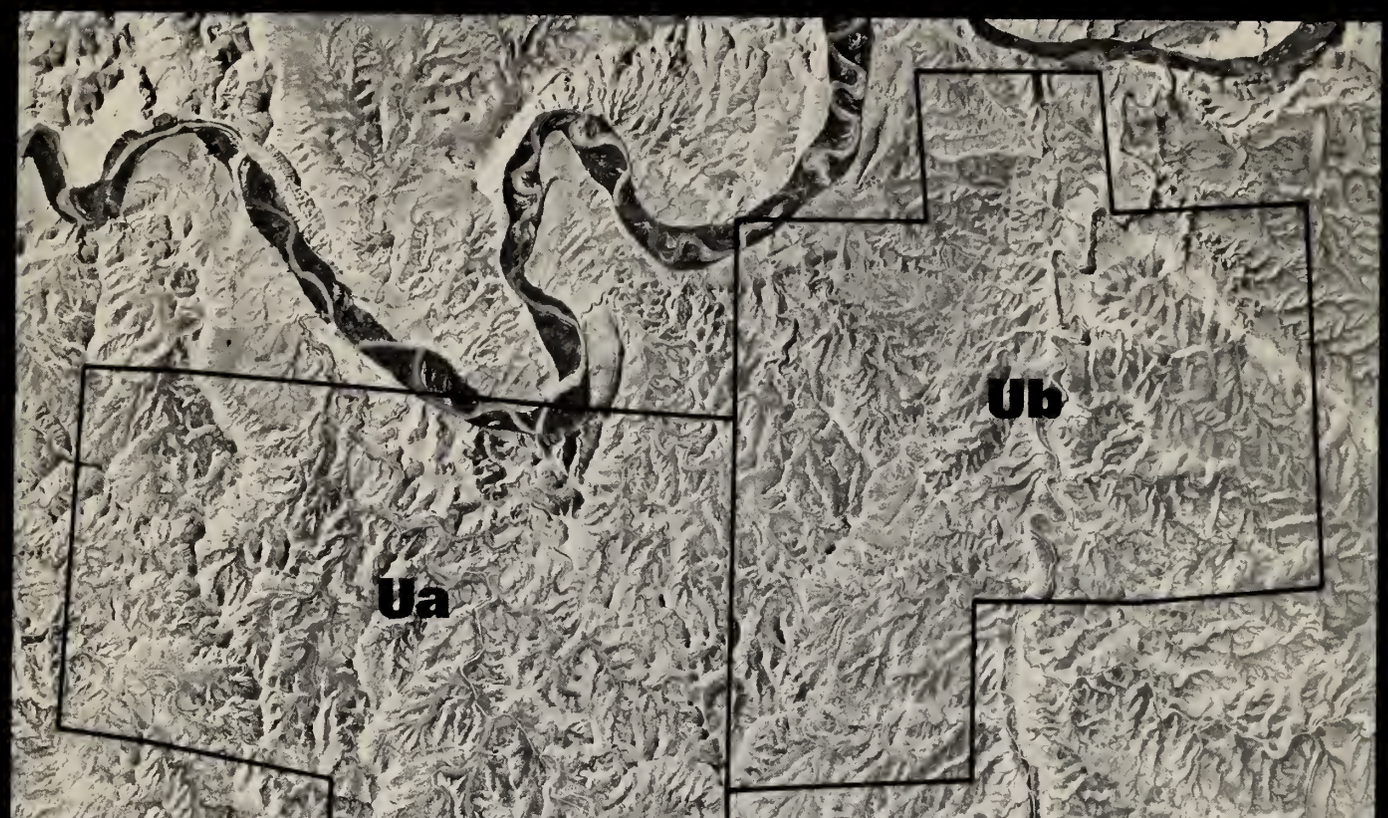
FIRST YEAR ENVIRONMENTAL BASELINE REPORT

VOLUME 1



FEDERAL PROTOTYPE OIL SHALE LEASING PROGRAM

TRACTS U-a and U-b

UTAH

WHITE RIVER SHALE PROJECT

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FIRST YEAR
ENVIRONMENTAL BASELINE REPORT

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D-[illegible], Building 50
Denver Federal Center
P. O. Box 25047
Denver, CO 80225-0047

FEDERAL PROTOTYPE OIL SHALE LEASING PROGRAM

TRACTS U-a AND U-b
UTAH

WHITE RIVER SHALE PROJECT

VTN Colorado, Inc.
May 1976

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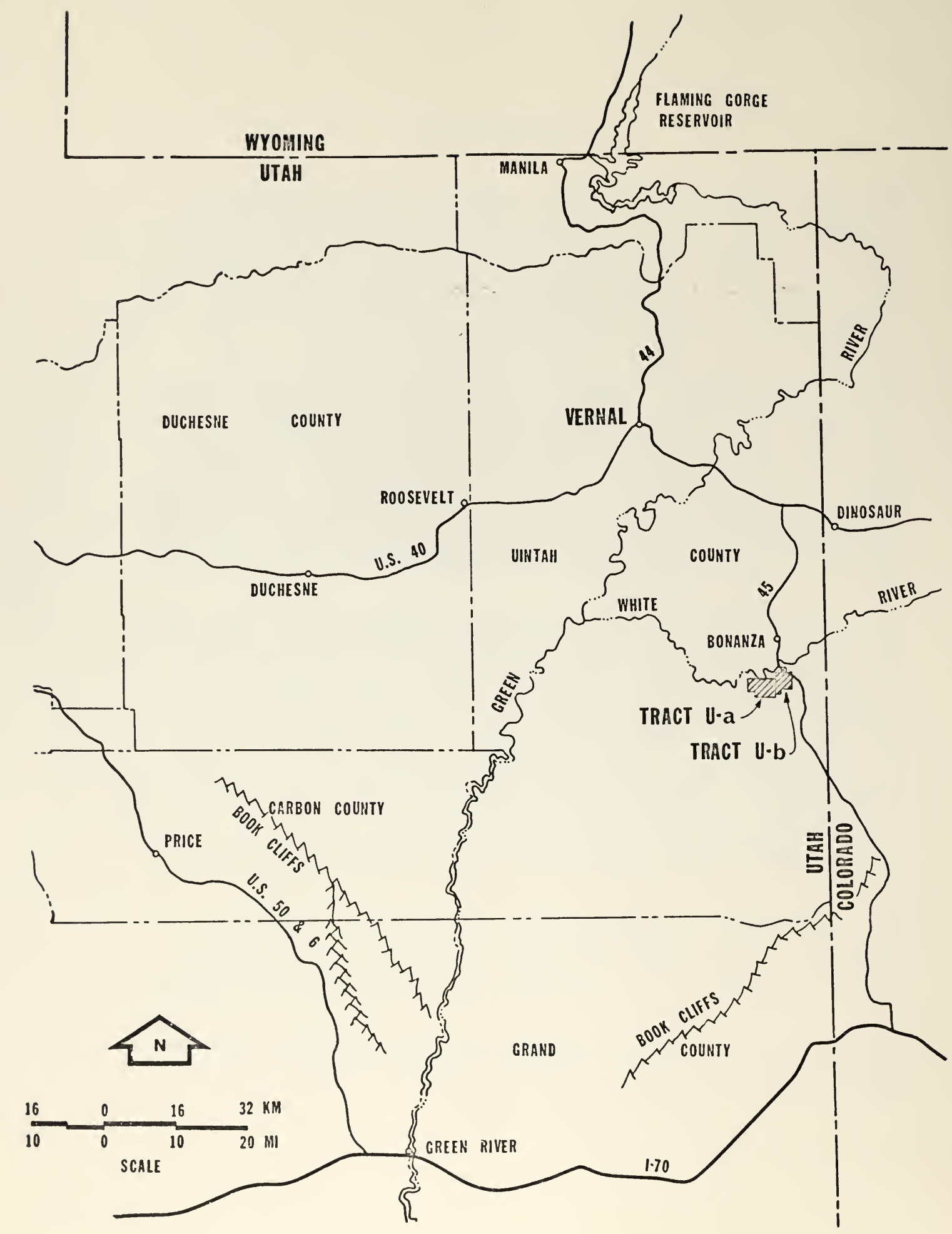
I
INTRODUCTION



PROJECT LOCATION MAP
TRACTS U-a & U-b

FIGURE 1-1

II WATER RESOURCES

II. WATER RESOURCES

A. OBJECTIVES

1. SURFACE WATER HYDROLOGY

The prototype oil-shale leasing program requires that surface water be described in terms of its quantity and quality in all principal stream courses draining the lease tracts. Baseline conditions are to be established upstream and downstream of each tract. According to the Lease Stipulations and Conditions of Approval the baseline data collection program is designed to provide the following:

1. Streamflow quantities
2. Stream chemical water quality
3. Suspended-sediment loads in streams
4. Precipitation patterns and amounts
5. Bottom-sediment chemistry and size distribution
6. Evaporation quantities

The objectives of the first-year baseline data report are summarization of the findings and conclusions. The Area Oil Shale Supervisor (AOSS) designated January 15, 1976, as the end of the first year of baseline data collection. The established reporting period in surface water investigations is the Water Year, from October 1 to September 30, which includes high-flow and low-flow periods. Any other time periods--either longer or shorter than the water year--will unfavorably bias the data toward either high-flow or low-flow events normally occurring during a complete seasonal cycle; therefore, even though data were collected through January 15, 1976, the conclusions will be based on the water year.

2. GROUND WATER HYDROLOGY

Prior to the baseline data collection program, there was very little known about the ground water hydrology of the southeast Uinta Basin. Previous investigators had studied yield and chemical quality, but their information was based primarily on data from springs and existing water wells (e.g. Austin and Skogerboe 1970; Price and Miller 1974; Feltis 1968 [b]). Because one of the principal objectives of the prototype leasing program is to determine the environmental impacts of oil shale extraction, the primary goal of

the ground water baseline data collection program is to define and monitor the hydrology within Tracts U-a and U-b and the area in terms of--

(1) determining aquifers that may be potentially impacted by mining activities

(2) determining aquifer hydraulic properties

(3) defining and determining ground water movement and ground water level fluctuation

(4) defining ground water quality and monitoring changes in its quality

(5) determining sources of aquifer recharge and discharge areas

(6) defining the interrelationships that may exist between the ore zone, surface waters, and aquifers

(7) detecting subsurface moisture migration under potential processed shale sites

The ground water baseline data collection program began in mid-August 1974; drilling was completed in mid-November of 1974. Data pertaining to water levels, water quality, and aquifer tests were collected continually through January 15, 1976.

B. METHODOLOGY

1. SURFACE WATER HYDROLOGY

The surface water data are collected under a cooperative agreement between the state of Utah, the USGS (Salt Lake City), and VTN. During the first year, stream gauging and sample collecting was a joint effort between VTN and USGS. The USGS analyzed water-quality samples in the USGS-Salt Lake City laboratories; processed the continuous punched-tape records of specific conductance, temperature, and flow; and developed the flow-rating curves.

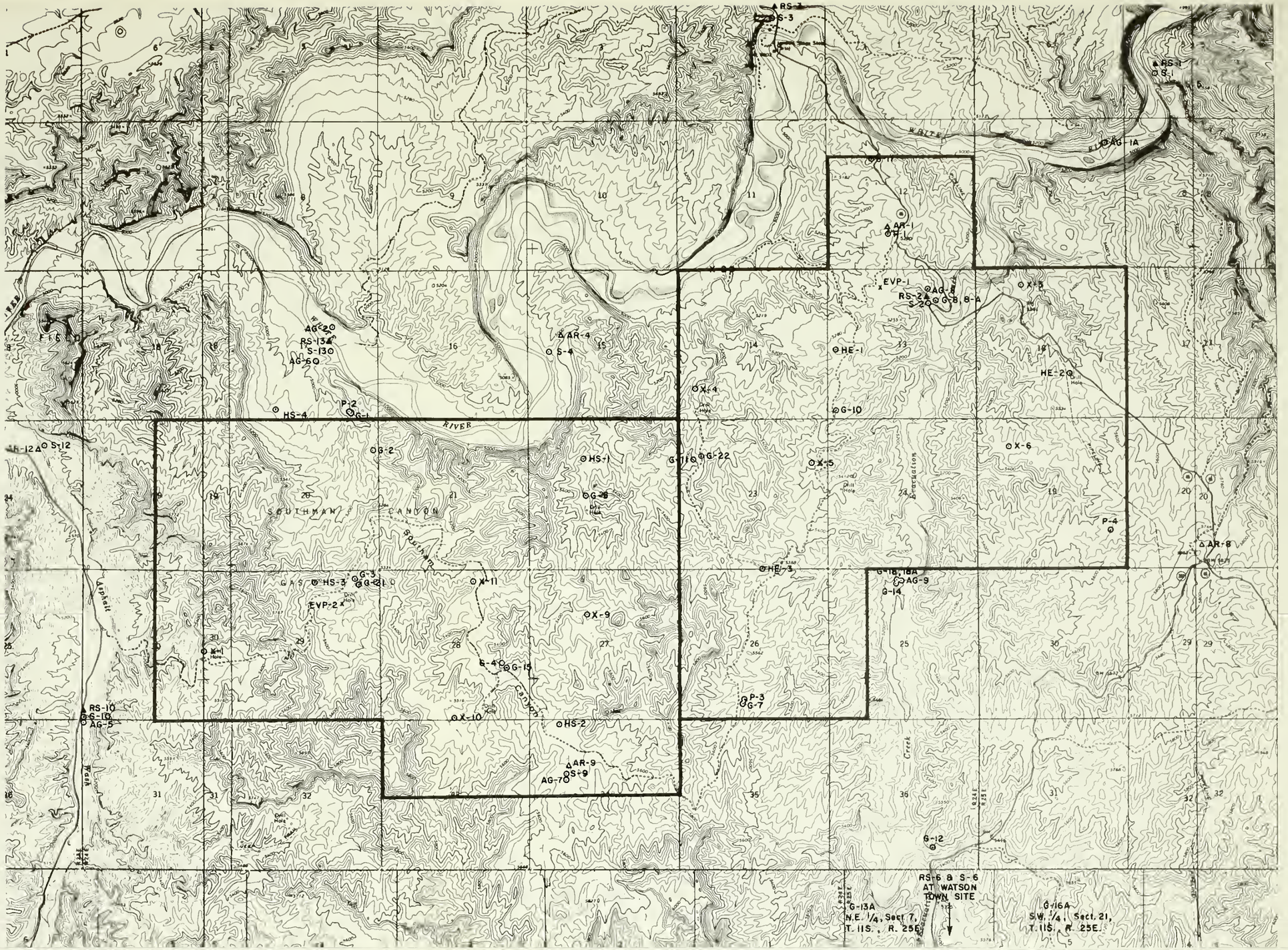
In all, 15 permanent surface water monitoring stations were installed on and near Tracts U-a and U-b (Figure II-1). Each station was installed with a stilling well and equipment to continuously record specific conductance, temperature, and flow. Four of these (stations S-1, S-3, S-4 and S-11) are in the White River, five are in Evacuation Creek or its tribu-

LEGEND

- ⊙ S — SURFACE WATER MONITORING STATION
- ⊙ P — PILOT TEST HOLE (WATER)
- ⊙ G — GROUND WATER MONITORING STATION
- ⊙ HE — EXISTING GEOLOGIC CORE HOLE, EVACUATION
- ⊙ HS — EXISTING GEOLOGIC CORE HOLE, SOUTHAM
- ⊙ X — EXPLORATION GEOLOGIC CORE HOLE
- ⊙ AG — ALLUVIAL WELL (WATER)
- △ AR — PRECIPITATION, AUTO (WATER)
- ▲ RS — PRECIPITATION, STORAGE (WATER)
- × EVP — EVAPORATION PAN (WATER)

1 0 1

SCALE IN MILES



WATER AND GEOLOGIC RESOURCES BASELINE MONITORING STATIONS

FIGURE II-1

taries (stations S-2, S-6, S-7, S-8. S-15). two are in Southam Canyon (stations S-9, S-13), two are in Asphalt Wash (stations S-10, S-12), and one is in Hells Hole Canyon (Station S-5). All stations are operated throughout the year, or as directed by the Area Oil Shale Supervisor's Office (AOSO), and are visited at least twice a month by VTN and USGS.

Precipitation is monitored at locations on and around the tracts using standard-recording and continuous-recording (cammed to punch at 5-minute intervals) weighing gauges. The locations of the gauges is shown on Figure II-1.

As directed by the AOSO, a precipitation water quality program was implemented in January 1976. Samples are to be collected upwind, near the center, and downwind of the tracts, by reconnaissance at the three locations using a plastic sheet and specially prepared sample bottles. Snow bottles have been collected; rain samples will be collected during late spring and early fall and during the summer thundershower period.

The locations of evaporation tanks with screened covers are shown on Figure II-1. During twice-weekly visits to the sites, water losses are recorded and the tanks refilled if required.

The design and construction part of the surface water baseline data collection program began in the field in July 1974. Stream-flow measurements, bottom-sediment sampling, and water-quality sampling were conducted in August 1974 at all the permanent installation sites, and all permanent installations were fully operational by October 1974. Collection of surface water data has continued uninterrupted through January 15, 1976.

2. GROUND WATER HYDROLOGY

The ground water hydrology of Tracts U-a and U-b and the vicinity is being studied using data obtained from aquifer wells, alluvial wells, and moisture monitoring wells. Four test-drilling sites, designated P-1 through P-4, were selected for subsurface drilling to locate any aquifers present and to study the stratigraphy and oil-shale properties beneath the tracts. The locations of the test sites are shown on Figure II-1. At each location, rotary air-drilling was used to collect continuous 8.9-cm (3.5-in.) core from the ground surface to a depth of about 122 m (400 ft) below the mahogany zone. At maximum intervals of 9.2 m (30 ft), the discharge fluids were measured for temperature, specific conductance, and flow quantities. A comprehensive suite of geophysical logs were run in these and subsequent

drill holes for additional subsurface information regarding stratigraphy, ground water, and oil shale. The log suite consisted of--

(1) gamma-ray

(2) gamma-gamma density

(3) neutron

(4) neutron-epithermal neutron

(5) flow

(6) temperature

(7) caliper

(8) SP

(9) resistivity

Each of the four sites were to be developed as aquifer test sites with a pumping well and two up-dip observation wells at distances of about 15 m and 40 m (50 ft and 150 ft) from the pumping hole. After drilling from August through mid-November 1974, sites P-1 and P-3 were completed as planned. Two aquifers were encountered at site P-2: the bird's nest aquifer and a thin, isolated zone above the bird's nest aquifer, found only at this location. The presence of these two aquifers necessitated two pumping wells and four observation wells. The aquifer was dry at P-4, and therefore only an observation hole was completed. One principal bedrock aquifer common to each of the four sites was found about 91.5 m (400 ft) above the mining zone. No additional aquifers were found below the principal bedrock aquifer. Fourteen additional wells were drilled and completed in this aquifer and in the vicinity of the tracts to determine ground water levels and quality.

Water-level sensing devices and punch-tape recorders, set to punch at 15-min intervals were used for continuous monitoring of ground water levels at the three P-sites. Water levels were measured on a monthly schedule in all other wells with steel tape or electric probes. Ground water chemistry was determined by analyzing pumped water samples collected from all available wells a minimum of once every six months.

Aquifers were tested at three of the four sites during late summer and early fall 1975. Submersible pumps with rates adjusted to the expected aquifer yield were used with porta-

ble generating equipment. The test results were used to determine aquifer interrelationships and aquifer/surface water interrelationships. Additional data were obtained from detailed mapping of aquifer outcrops.

Five alluvial wells were installed in the Southam Canyon and Evacuation Creek drainages. Water levels were monitored routinely and samples were collected monthly for analysis when the alluvium contained water. Twelve additional alluvial wells installed in January 1976 will be included in the program for the second year of baseline data collection.

Eight wells distributed throughout the Southam Canyon and Evacuation Creek drainages (proposed processed-shale disposal sites) were drilled and completed for studying moisture migration in the first few hundred meters of bedrock underlying the drainages. These and other selected wells have been logged quarterly using a combination of gamma-ray and neutron tools.

C. SUMMARY OF RESULTS

1. SURFACE WATER RESOURCES

The project is in the Colorado River Basin, in which most of the streams originate high in the Rocky Mountains. From their points of origin, the streams flow through semi-arid regions and then through deserts as the tributaries combine to form the major rivers of the basin.

Most of the water within the streams comes from mountain sources. On a yearly average, streamflows increase rapidly as the streams pass through the mountains but increase only slightly in the semi-arid regions and may actually decrease in the desert regions as a result of evaporation.

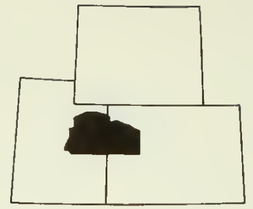
Streamflows change with the seasons. During fall, flows are typically low because of the small amount of precipitation. Winter precipitation is in the form of snow and does not contribute to streamflow until it melts during spring. Streamflows diminish during summer as water sources that were replenished by snowmelt gradually drain.

Water quality is generally best in the mountains and gradually deteriorates as the water flows through the arid regions. In the higher regions quality is not a limiting factor in water use, but in the lower regions the gradual decline in quality as a result of evaporation and the generally poor quality of tributaries in the arid and semi-arid regions is restricting for some uses.

Within the Colorado River system, the project area lies within the White River drainage of the semi-arid Uinta Basin (Figure II-2). The White River itself passes through the northern portion of the project area, where only one other stream, Evacuation Creek, has sustained flow. Historic streamflow records are available from USGS gauging stations at several points along the White River, but none of the other streams in the project area had been gauged before the baseline monitoring program began. Similarly, historic water-quality data are available from the USGS for the White River but not for the other drainages.

LEGEND

- ● CLIMATIC STATION
- ○ GAGING STATION
- ■ U-a& U-b OIL SHALE SURFACE WATER MONITORING STATIONS
- ⊘ USGS GAGING STATIONS TO BE INSTALLED
- ⊕ USGS INSTALLED GAGING STATIONS



INDEX MAP

SOURCE: IORNS, HEMOREE AND OAKLAND, 1980.

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SCALE IN MILES

LOCATION OF SURFACE, CLIMATOLOGIC STATIONS AND SAMPLING SITES IN THE UPPER COLORADO RIVER BASIN

FIGURE II-2

a. Hydrology

Study-Area Precipitation

Little precipitation or evaporation data is available for the project area previous to the baseline monitoring program. Perhaps the best source of information is a report entitled Hydrologic Inventory of the Uintah Study Unit (Austin and Skogerboe 1970), in which the entire basin is interpreted based on all relevant historic data.

As shown on Figure II-3 the average annual precipitation for the project area is about 25.4 cm (10 in.). Precipitation varies from about 23 cm (9 in.) in the northwest tract area to 28 cm (11 in.) in the southeast tract area. The results of the first year of precipitation gauging are shown on Figure II-4. As seen in the comparison of historic and first-year precipitation data (figures II-3 and II-4), precipitation during the first year was about average for the region except for the greater detail provided by the baseline gauging network.

Annual precipitation can be discussed more specifically in terms of annual snowfall and rainfall. Figures II-5 and II-6 indicate the historic average October-April (snowfall) and May-September (rainfall) precipitation, respectively, in the region. Comparison of these figures with figures II-7 and II-8, which represent the equivalent periods during the first year of monitoring, demonstrates that the distribution of snowfall and rainfall were also average for the region.

Rainfall and snowfall patterns are different across the project area. Snowfall tends to be evenly distributed because snow storms are usually regional in extent. Rainfall, on the other hand, is greatly influenced by local terrain.

Major features, such as canyons and ridges, affect rainfall distribution through orographic stimulation and atmospheric evaporation. Orographic stimulation is the process in which land features cause air flow to move into a colder environment, thus promoting condensation and precipitation. The ridges between drainages in the project area are high enough to have some effect on thunderstorms. The storm track in the area is generally from southwest to northeast and, as can be expected, the rainfall is heavier on the top of the ridges.

Evaporation of rain in the atmosphere can also cause precipitation to vary. Precipitation is heavier on the higher land, since the shorter distance the rain travels allows less time for loss through evaporation. To determine the signifi-

cance of elevation on precipitation, the first year's data were analyzed using linear regression. The results indicate that annual precipitation increases about 8.2 cm (3.2 in.) with every 300 m (1000 ft) of additional elevation.

The potential evaporation in the project area, measured by the pan evaporation rate, was about 110 cm (39 in.) from May through September and was just slightly less than 24 cm (9.4 in.) in July. Considering the high temperatures and low humidity of the area during summer, these values are not unusual. Because of the evaporation rate and the amount of precipitation, only very intense rainfall can contribute to streamflow.

Study-Area Streamflow

The hydrology of the project area will be further analyzed in discussing the White River, Evacuation Creek, and the dry washes.

White River: In addition to the USGS station already established (Figure II-1), three new streamflow-monitoring sites were established on the White River for the surface water program.

Station	Location
S-1	Upstream of Tract U-b just above the mouth of Hells Hole Canyon.
S-3	Near Ignacio Stage Stop and Watson, Utah. This USGS station was augmented for use in the program.
S-4	Upstream of Tract U-a and downstream of Tract U-b.
S-11	Below the mouth of Asphalt Wash, downstream of Tract U-a.

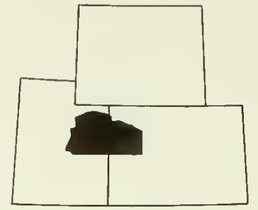
Historic Flows: The White River gains little flow in the vicinity of the project area. Using the 1951-1960 records from the USGS gauge below Meeker, Colorado, and the USGS gauge at Station S-3, the streamflow in the White River increased less than 5 percent in the 162-km (100-mi) reach between these two stations.

LEGEND

40

ISOHEYTAL LINES SHOWING AVERAGE ANNUAL PRECIPITATION, IN INCHES

ISOHEYTAL INTERVAL	
2"	BELOW 12"
4"	12"-20"
5"	20"-30"
10"	ABOVE 30"



INDEX MAP

SOURCE: IORNS, HEMBREE AND OAKLAND, 1960.

N

5 4 0 8

SCALE IN MILES

ISOHYETAL MAP OF UPPER COLORADO RIVER BASIN SHOWING AVERAGE ANNUAL PRECIPITATION

FIGURE II-3

LEGEND

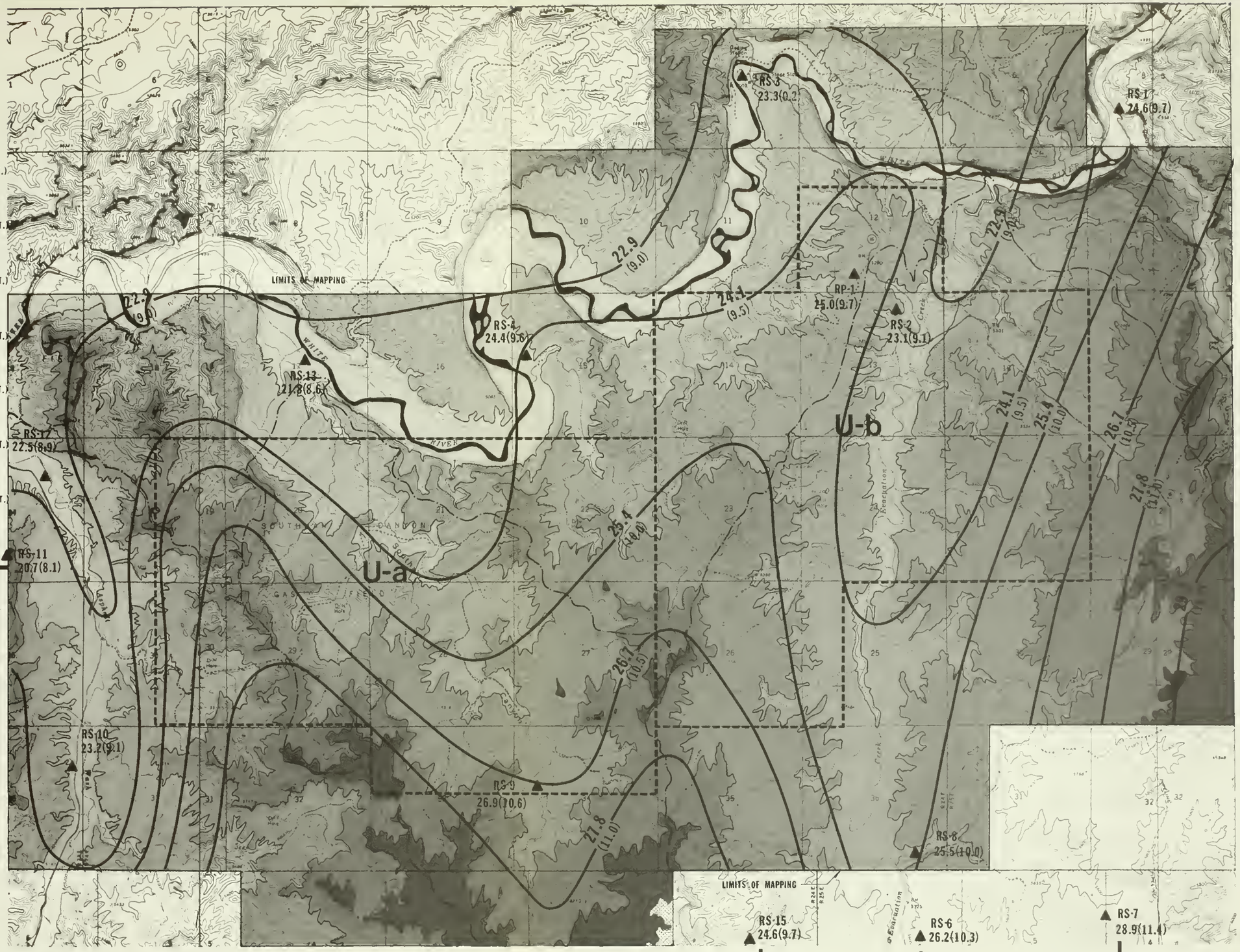
ELEVATION

- 1463-1524 METERS(4800-5000 FT.)
- 1524-1585 METERS(5000-5200 FT.)
- 1585-1646 METERS(5200-5400 FT.)
- 1646-1707 METERS(5400-5600 FT.)
- 1707-1768 METERS(5600-5800 FT.)
- 1768-1829 METERS(5800-6000 FT.)
- 1829-1890 METERS(6000-6200 FT.)
- WATERSHED BOUNDARY
- 00 (0.0) PRECIPITATION ISOHYETAL
- ▲ MANUAL PRECIPITATION GAUGES CM(IN) YEAR AVERAGE

N

2000 0 2000

SCALE IN FEET



PRECIPITATION MAP

OCTOBER 1974 - SEPTEMBER 1975

CM(IN)

FIGURE II-4

LEGEND

40

ISOHEYTAL LINES SHOWING AVERAGE ANNUAL PRECIPITATION, IN INCHES

ISOHEYTAL INTERVAL	
2"	BELOW 12"
4"	12"-20"
5"	20"-30"
10"	ABOVE 30"

INDEX MAP

SOURCE: TORNS, HEMBREE AND DARLAND, 1960.

N

8 4 0 8

SCALE IN MILES

ISOHYETAL MAP OF UPPER COLORADO RIVER BASIN SHOWING AVERAGE OCTOBER-APRIL PRECIPITATION

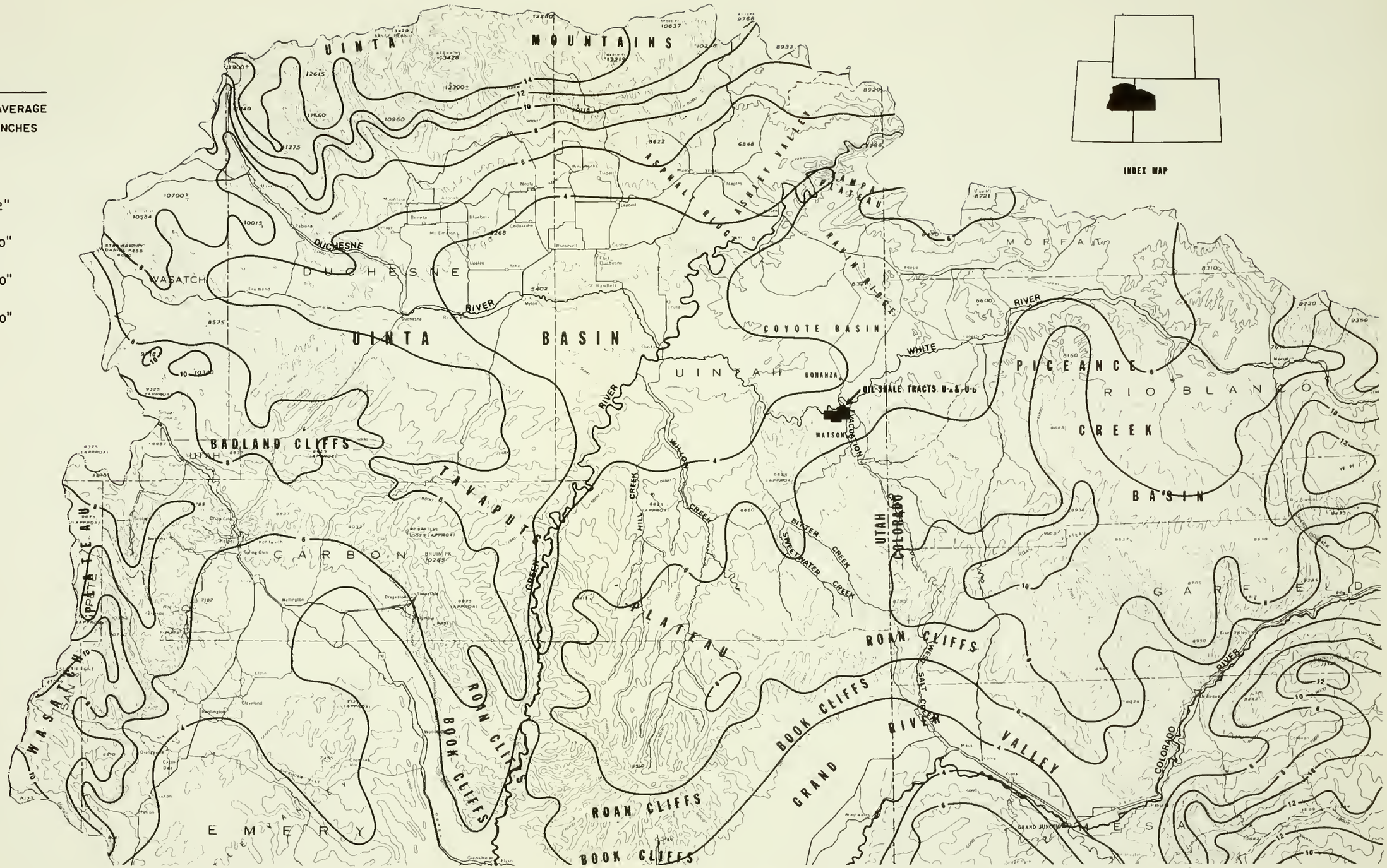
FIGURE II-5

LEGEND

—40— ISOHEYTAL LINES SHOWING AVERAGE ANNUAL PRECIPITATION, IN INCHES

ISOHEYTAL INTERVAL	
2"	BELOW 12"
4"	12"-20"
5"	20"-30"
10"	ABOVE 30"

INDEX MAP



SOURCE: TORNS, HEMBREE AND OAKLAND, 1960.

N

8 4 0 8

SCALE IN MILES

ISOHYETAL MAP OF UPPER COLORADO RIVER BASIN SHOWING AVERAGE MAY-SEPTEMBER PRECIPITATION

FIGURE II-6

LEGEND

ELEVATION

- 1463-1524 METERS(4800-5000 FT.)
- 1524-1585 METERS(5000-5200 FT.)
- 1585-1646 METERS(5200-5400 FT.)
- 1646-1707 METERS(5400-5600 FT.)
- 1707-1768 METERS(5600-5800 FT.)
- 1768-1829 METERS(5800-6000 FT.)
- 1829-1890 METERS(6000-6200 FT.)

WATERSHED BOUNDARY

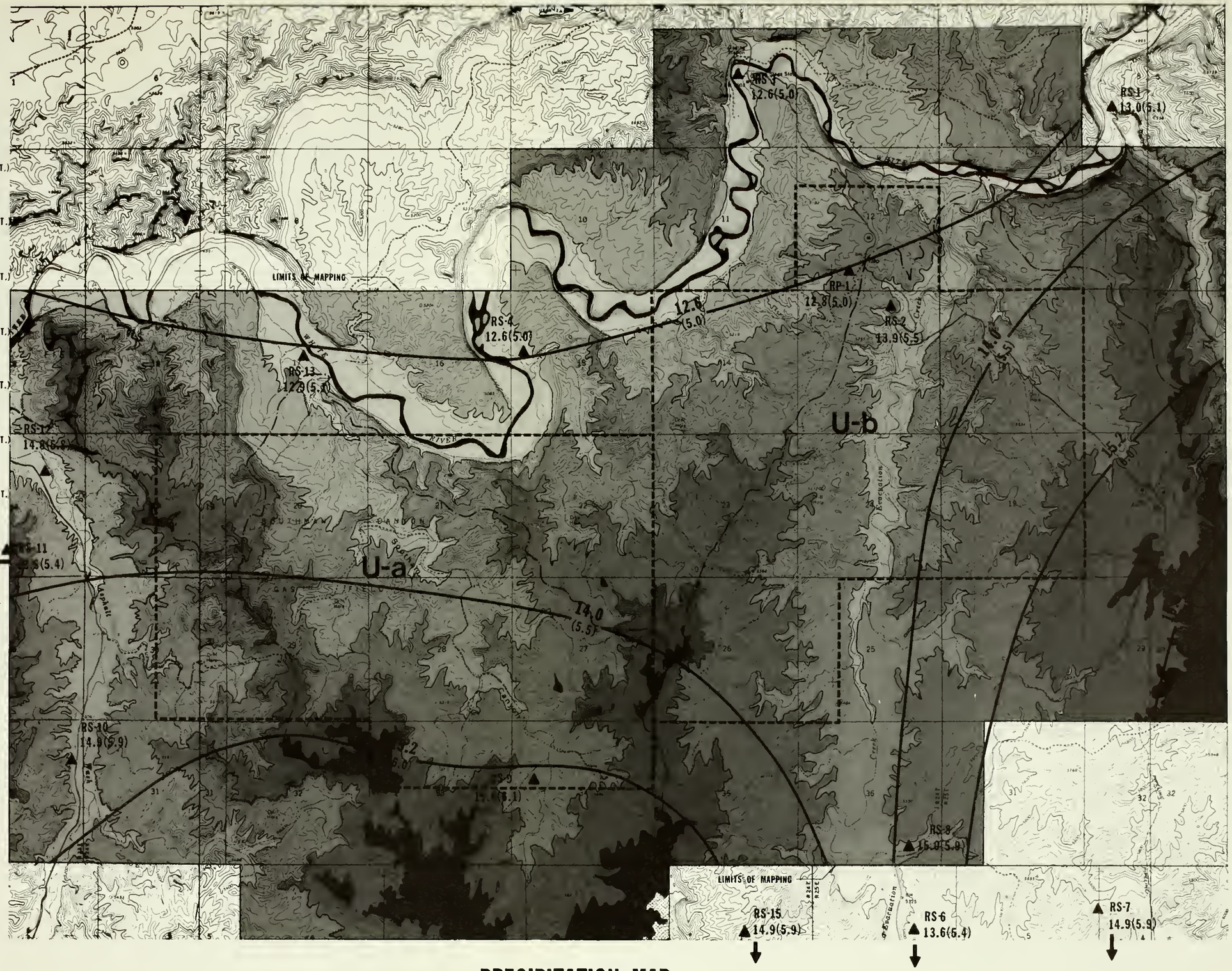
00 (0.0) PRECIPITATION ISOHYETAL

▲ MANUAL PRECIPITATION GAUGES CM(IN) PARTIAL YEAR TOTAL

N

2000 0 2000

SCALE IN FEET



PRECIPITATION MAP

OCTOBER 1974 - APRIL 1975

CM(IN)

FIGURE II-7

LEGEND

ELEVATION

- 1463-1524 METERS(4800-5000 FT.)
- 1524-1585 METERS(5000-5200 FT.)
- 1585-1646 METERS(5200-5400 FT.)
- 1646-1707 METERS(5400-5600 FT.)
- 1707-1768 METERS(5600-5800 FT.)
- 1768-1829 METERS(5800-6000 FT.)
- 1829-1890 METERS(6000-6200 FT.)
- WATERSHED BOUNDARY
- 00 (0.0) PRECIPITATION ISOHYETAL
- ▲ MANUAL PRECIPITATION GAUGES CM(IN) PARTIAL YEAR TOTAL
- △ AUTOMATIC PRECIPITATION GAUGES CM(IN) PARTIAL YEAR TOTAL

N

2000 0 2000

SCALE IN FEET

LIMITS OF MAPPING

RS-3 0.7(4.2)

RS-1 11.6(4.6)

RP-1 12.3(4.8)

RS-2 9.2(3.6)

RS-4 11.8(4.6)

RS-12 8.8(3.5)

RS-17 7.8(3.4)

RS-11 7.0(2.8)

U-a

U-b

AR-2 13.0(5.1)

RS-10 8.3(3.3)

RS-9 11.4(4.5)

AR-4 14.2(5.6)

RS-8 10.4(4.1)

RS-15 9.7(3.8)

RS-6 12.7(5.0)

RS-7 14.0(5.5)

PRECIPITATION MAP

MAY 1975 - SEPTEMBER 1975

CM (IN)

FIGURE II-8

According to data from Station S-3, the historic annual average flow of the White River--19.9 m^3/s (702 cfs)--has been relatively consistent from year to year. Within any one year, however, the flow fluctuates drastically, as shown on Figure II-9. For the most part, these variations are caused by snowmelt in the eastern mountain regions of the basin between May and July. The streamflow during the other months is mostly the result of ground water seepage and to a lesser extent, surface runoff from rainstorms. For easy reference, the months in which snowmelt contributes substantially to streamflow will be referred to as high flow, and during the other months streamflow will be referred to as baseflow.

Figure II-9 gives an idea of the magnitude of maximum and minimum flows; a more precise method may be used to calculate the probabilities of high and low flows. Using data from the station's entire period of record, high and low flows of various durations may be calculated in terms of the probability of their occurrence in a particular year. The USGS data from Station S-3 for the period of record were analyzed using this method (Figure II-10).

Several facts are worth noting in Figure II-10. Although the high flows of 1-day duration and 30-day duration differ in magnitude throughout the range of probabilities, the 1-day and 30-day low flows tend toward similar magnitudes for frequent (i.e., high probability) events, indicating that the baseflow of the White River is fairly regular, since the average daily flow for most 30-day periods is historically similar to the average daily flow for any one day. Figure II-10 also indicates that an average daily flow of less than 1.27 m^3/s (45 cfs) at Station S-3 in the White River is very unlikely (less than 1 percent probability), and an average 7-day flow of less than 2.27 m^3/s (80 cfs) is equally unlikely (less than 1 percent probability).

Preliminary determinations of mean daily stream flows for stations S-1, S-3, S-4 and S-11 are shown on figures II-11 through II-14, respectively. Specific conductance and water-temperature data for the year are also shown on these figures because these parameters can be useful in determining sources of streamflow.

As indicated in figures II-11 through II-14, streamflow did not vary significantly between the stations. Beginning with the station furthest upstream, the total volume of water passing each station during the water year was as follows:

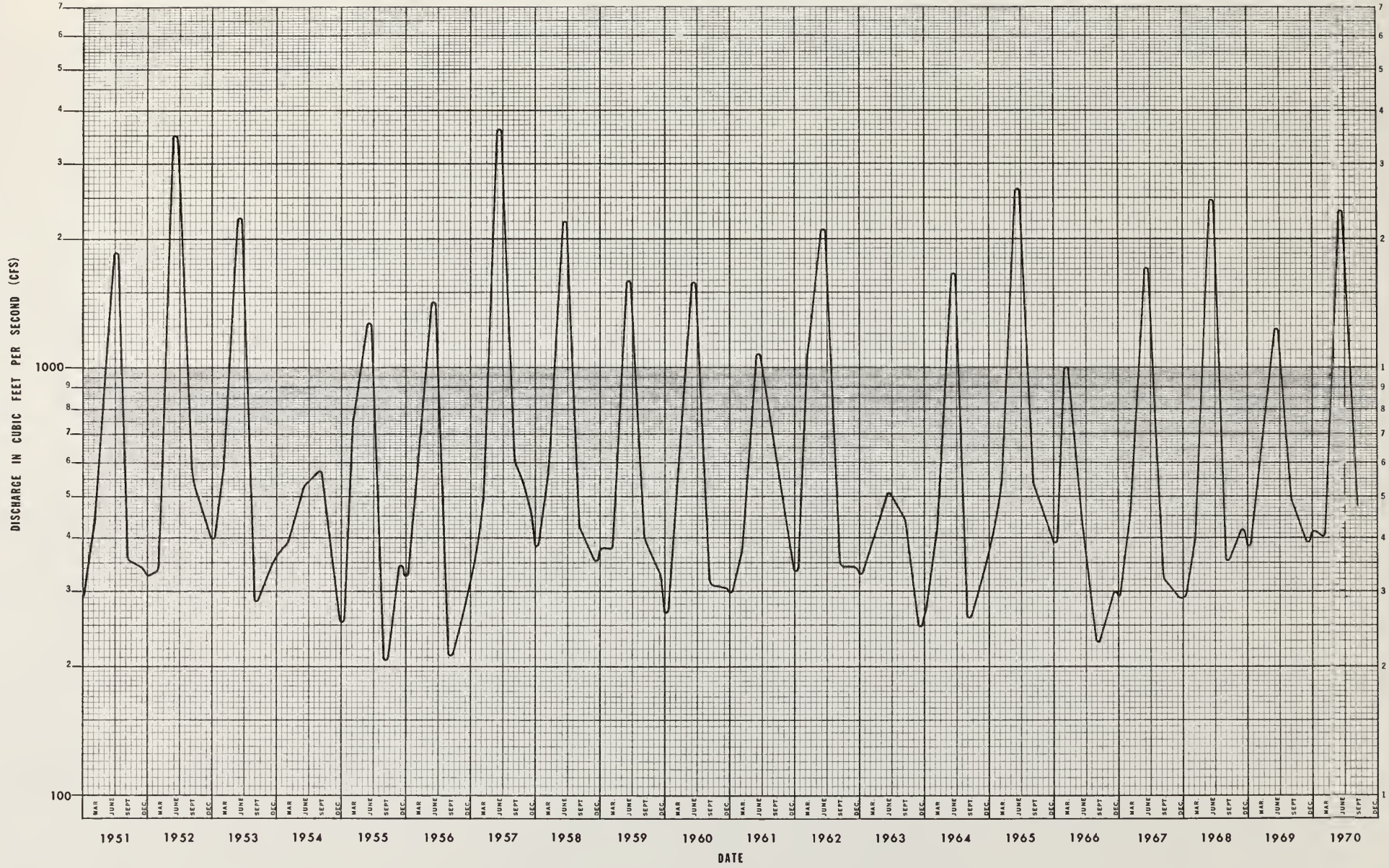
Station	Volume of Water (hectare-meters)	Volume of Water (acre-feet)
S-1	65,500	531,000
S-3	67,000	544,000
S-4	67,000	544,000
S-11	68,000	551,000

The 4 percent difference between the high and low figures is well within the accepted measurement accuracy for streamflows calculated from stage measurements. Flow volumes are therefore essentially the same at all four stations. Although not reflected in mean daily flows, there were discernible differences between flows at the four stations for periods of several hours on days that water flowed in the normally dry washes of the study area.

During the first year of monitoring, the highest average daily flow at each of the gauging stations along the White River was as follows:

Station	Highest Average Daily Flow (m^3/s)	Highest Average Daily Flow (cfs)
S-1	110	3900
S-3	108	3810
S-4	111	3910
S-11	119	4190

The highest average daily flow at these stations was between June 9 and June 10, 1975. Since only stations S-3 and S-11 are operated during the ice period of November through March, average daily flows are determined for stations S-3 and S-11 and are then extrapolated for stations S-1 and S-4. The lowest average daily flow (5 m^3/s or 180 cfs) occurred December 26, 1975. A comparison of these figures with those of Figure II-10 indicates that neither flow event was unusual: the high flow was an event with a five-year recurrence interval, and the low flow was an event with a two-year recurrence interval.

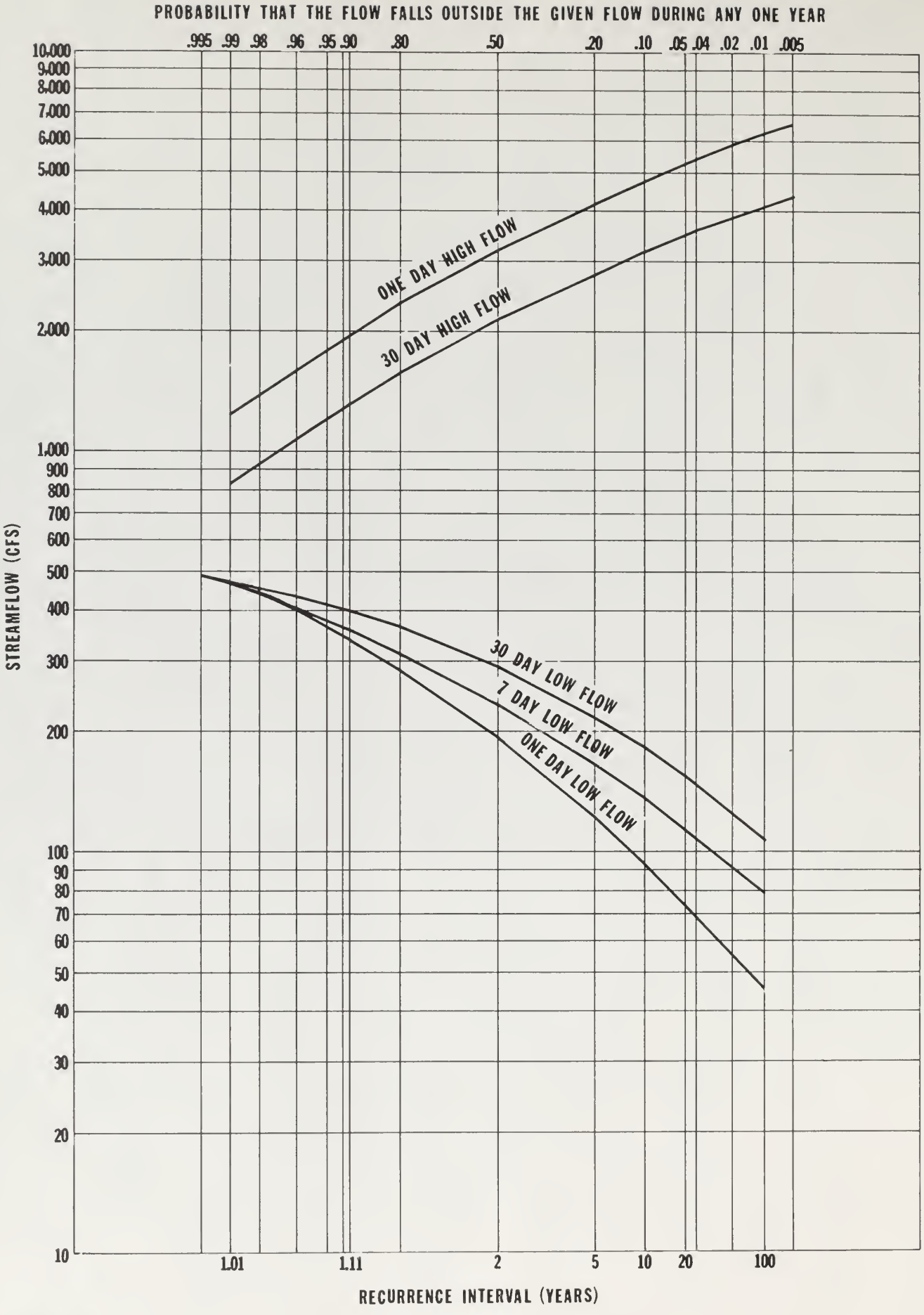


WHITE RIVER 20 YEAR HYDROGRAPH

WHITE RIVER NEAR WATSON (9-6500)

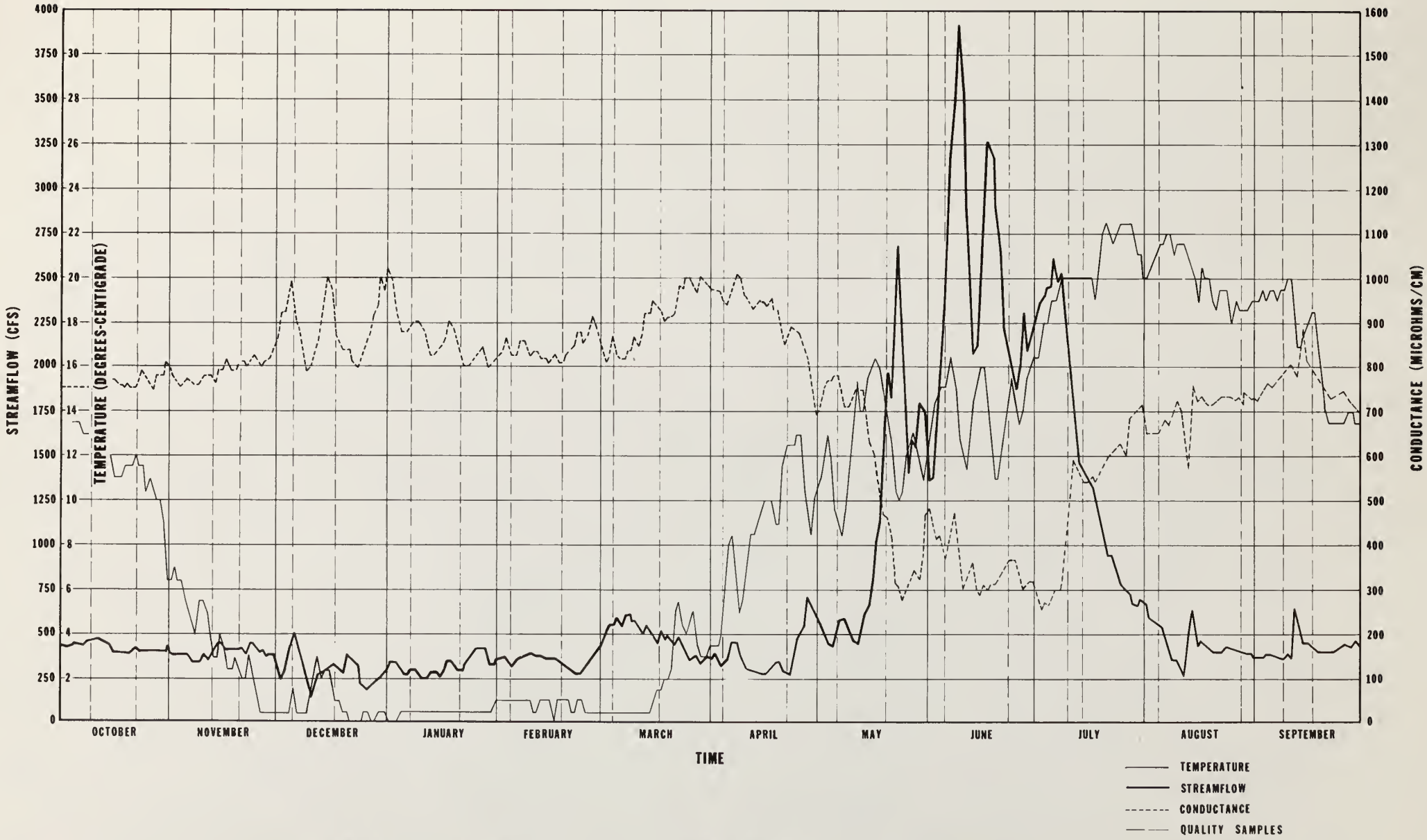
SOURCE: USGS

FIGURE II-9



WHITE RIVER HIGH AND LOW FLOW ANALYSIS

FIGURE II-10

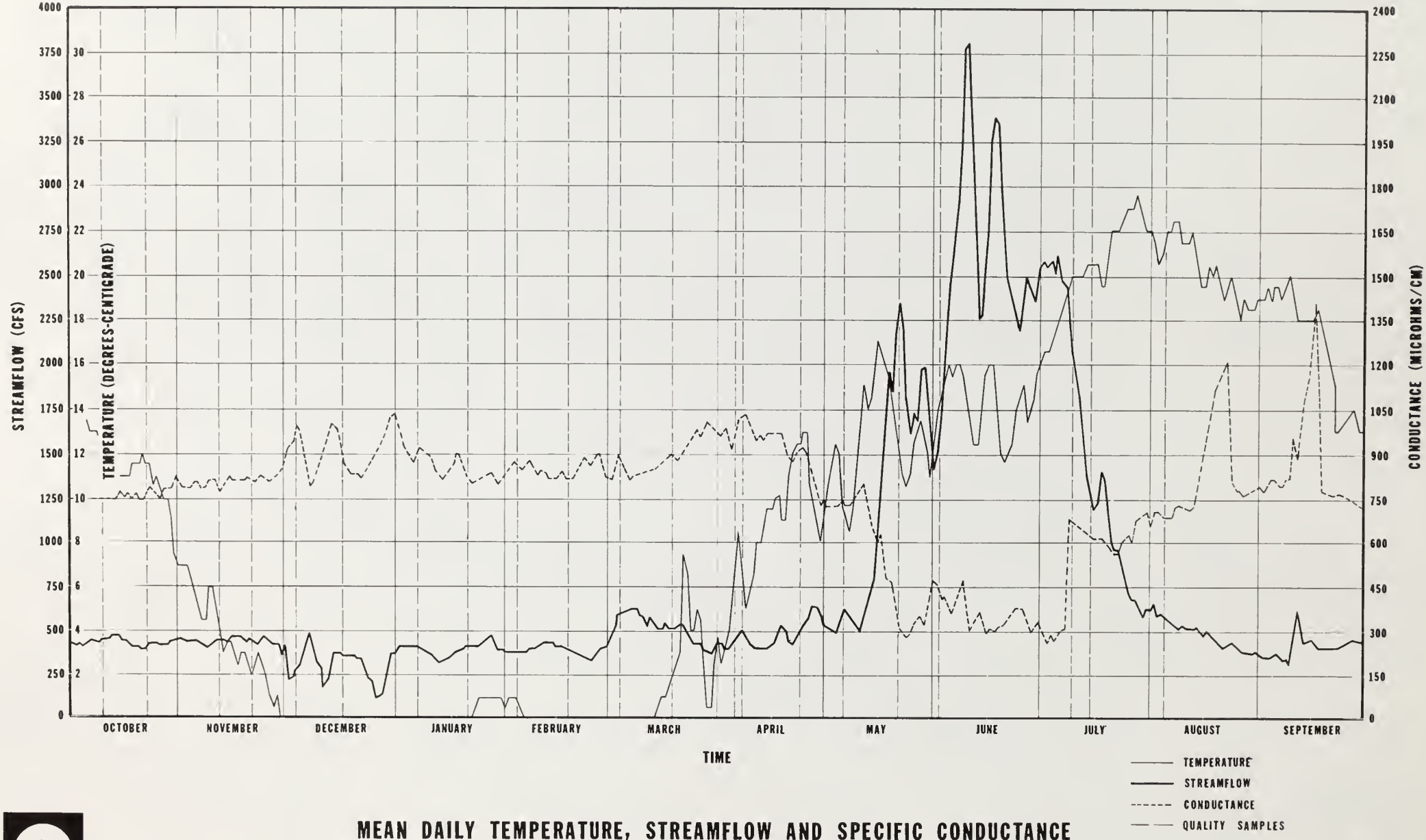


MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

WHITE RIVER ABOVE HELLS HOLE CANYON - (S-1)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-11

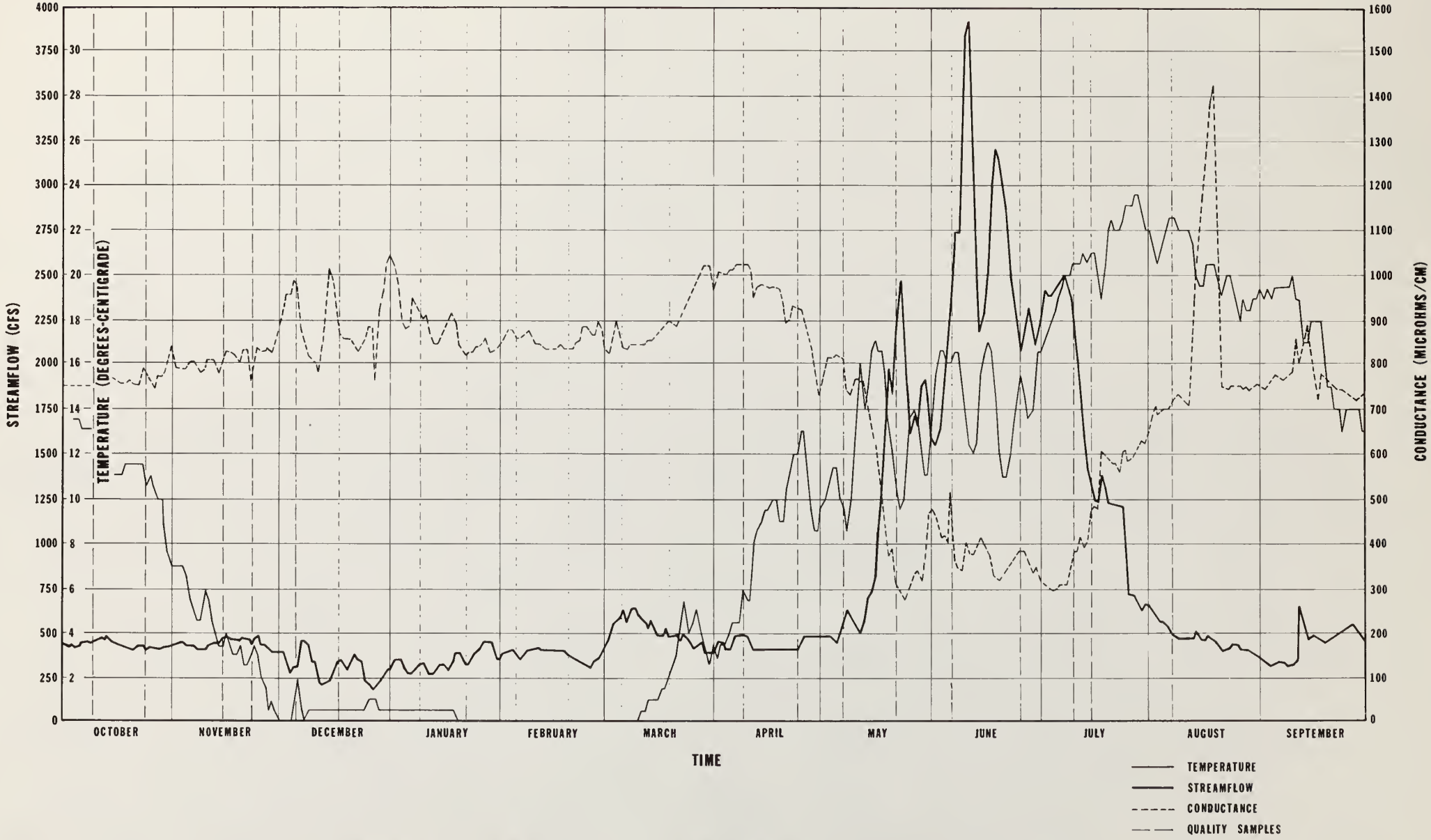


MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

WHITE RIVER NEAR WATSON, UTAH - (S-3)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-12

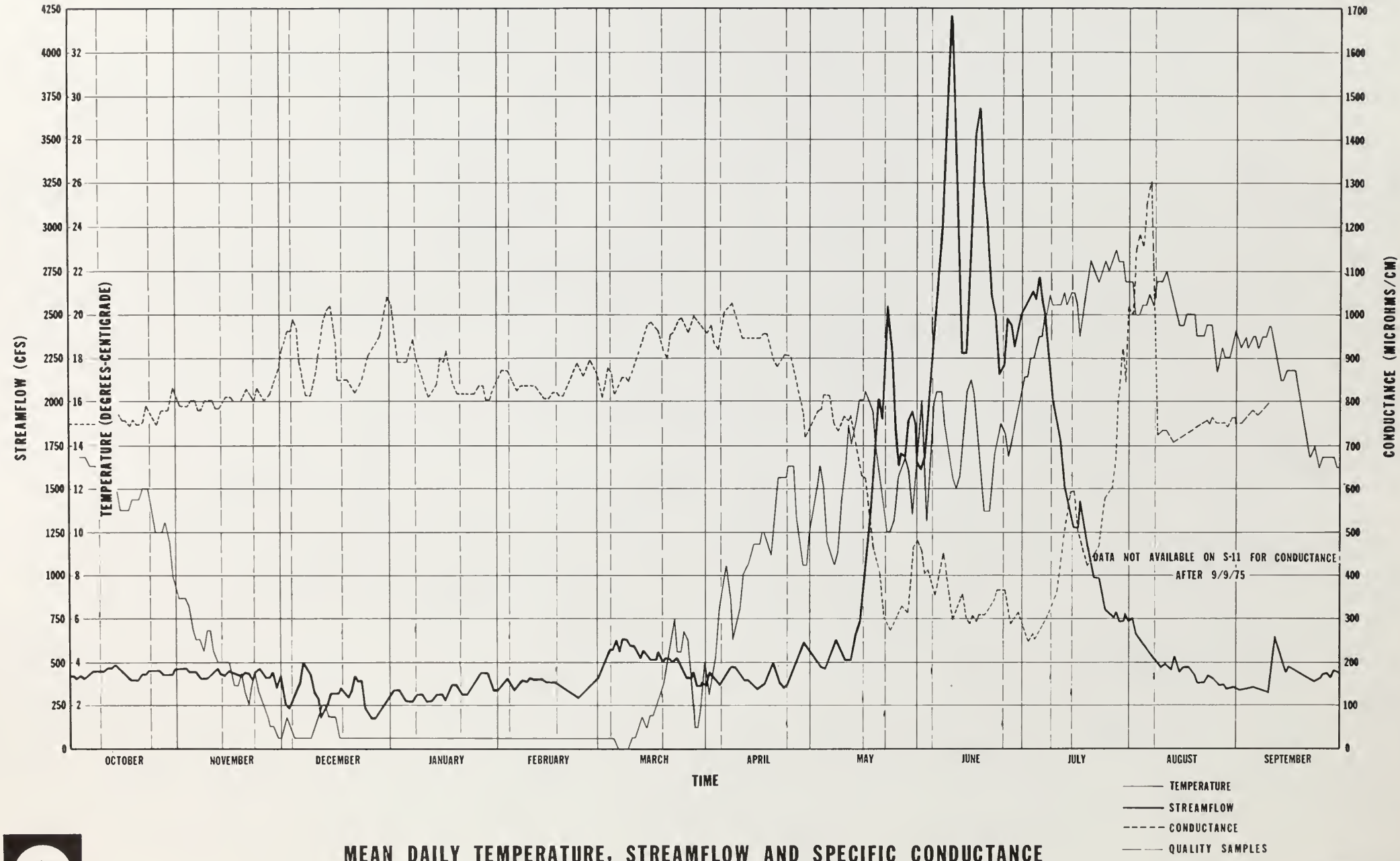


MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

WHITE RIVER ABOVE SOUTHAM CANYON - (S-4)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-13



MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

WHITE RIVER BELOW ASPHALT WASH - (S-11)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-14

First-Year Flow Pattern: Preliminary mean flow calculations for Station S-3 indicate that the mean flow (21.3 m^3/s; 715 cfs) for the first year of monitoring was very similar to the historic mean flow (19.9 m^3/s; 702 cfs) at Station S-3. The first-year mean flow was apparently 7 percent higher than the historic mean flow--a difference well within the measurement accuracy of the methodology. As a whole, then, streamflow for the year must be considered average or perhaps slightly above average. The distribution of the flows within the year, however, were not average. Snowmelt in the high mountains was later than usual, so that April flows were only 65 percent of the historic average for that month. During May, streamflow was about 74 percent of the average, but in June streamflow was 208 percent of the average. The flow in July was 202 percent of the average but returned to average in August. During the baseflow months, flows were about 93 percent of the average. The late snowmelt and the corresponding late high-flow period were advantageous to this study because the water sources were clearly separate on the streamflow, conductance and temperature records.

Specific conductance is directly proportional to the dissolved solids content and can be used to determine the water source. For example, ground water seepage can often be identified because the levels of dissolved solids (and thus specific conductance) are typically higher in ground water than in surface runoff. (Ground water can be further identified by its variations from one area to another.) Furthermore, ground water seepage occurs at a constant rate throughout the year, while surface runoff varies with atmospheric conditions.

From October through February, most of the water in the White River was from ground water seepage in the upper basin, as indicated by the consistent flow and moderate specific-conductance levels. In late February and early March, flow increased from snowmelt in the lower basin (which includes the project area), as inferred from stream-gauge records in the lower basin. Streamflow gradually decreased into April. This gradual decrease after high flows is typical of flow patterns originating from water released from storage in the stream banks, water seeping through the soil, and water discharged from replenished aquifers. Since ground water in the lower basin is typically higher in dissolved solids than that of the upper basin, the higher specific conductance of the post-peak flows indicates that lower-basin ground water seepage contributed to streamflow in the White River during late March and April.

Upper basin snowmelt began in mid-May, as indicated by the extreme increase in streamflow and the decrease in specific conductance. Specific conductance decreases at this time because the dissolved-solids content of the surface runoff

in the upper basin is much lower than that of the ground water. (This is not the case in the lower-basin surface runoff, because the normally dry streambeds contain many evaporites that are quickly dissolved by the snowmelt. Upper-basin streambeds, however, are flushed year-round by continuous flows and therefore do not contain such evaporites.) The snowmelt and runoff from the upper basin cause the White River to fluctuate widely over relatively short time periods. In July, flows decrease as the snow disappears, and by August the White River is again at baseflow.

The water temperature has three distinct patterns. The overall pattern shown on Figure II-11 is sinusoidal, directly following the yearly cycle of the air temperature, which is at a minimum in January and February and at a maximum in July and August.

The second temperature pattern shown on Figure II-11 reflects day-to-day and week-to-week temperature fluctuations as the proportion of ground water to surface water changes. The temperature of ground water seepage is fairly constant, approximately the average annual air temperature, and that of surface runoff from snowmelt or rainfall is usually at or below the air temperature at that time. Since ground water seepage occurs at a reasonably constant rate throughout the year, most of these short-term fluctuations in flow relate to changes in the percentage of surface runoff in streamflow. Thus, the pattern of short-term temperature fluctuations should usually be the opposite to that of flow fluctuations (i.e., increased flow, decreased temperature), as the records show.

The third temperature pattern reflects temperature changes during the high-flow months of May, June, and July, when on the average stream temperatures are lower than average. This decrease is thought to be at least partially the result of the higher stream velocities (and thus shorter travel times) during high streamflows. Since most of the flow in the White River comes from the upper basin, there is usually sufficient time for the stream temperature to equalize with the air temperature by the time the water reaches the project area (except for residual short-term fluctuations). As the stream velocity increases with increased volume from snowmelt, the time to reach equilibrium is shortened, and the water that began moving downstream at near freezing temperatures cannot quite reach equilibrium with the air temperature. As a result the temperatures recorded at all four stations on the White River decreased sharply in mid-May, coinciding with the beginning of runoff from snowmelt, and then increased until by mid-July they again followed the yearly cycle.

In addition to the expected trends in streamflow, the White River stations measured some unexpected trends in December. The lowest flows of the year were measured in three separate periods of sharply decreased streamflow during the month. The specific conductance record indicates that these periods were the result of decreased flow from the upper basin and that they may relate to ice formation in the river, since water temperatures decreased to freezing at the onset of this period. Since the fluctuations were not repeated in January or February when water temperatures were again at freezing, further study is necessary prior to any firm conclusions.

Evacuation Creek: Evacuation Creek drains approximately the eastern one-third of Tract U-b; its associated drainage extends far south of the tracts. The total drainage area of Evacuation Creek is about 770 km^2 (280 sq mi), 14.2 m^2 (5.5 sq mi) of which is within Tract U-b. For the baseline monitoring program five streamflow-gauging stations were established within the Evacuation Creek drainage (Figure II-1): three on the creek itself and two at the mouths of small tributary canyons. Station S-2 is downstream of the tracts and is about 3.2 km (2 mi) upstream of the confluence of the White River, where Utah Highway 45 crosses the creek. Station S-6 is upstream of the tracts and is at the abandoned Watson townsite. Station S-7, on Evacuation Creek above S-6, and stations S-8 and S-15, on small tributary canyons, were established for monitoring areas that might be affected if Evacuation Creek were used as a processed-shale disposal site but were deleted from the monitoring program because disposal is no longer planned for this area.

Historic Flows: Because there are no streamflow records for Evacuation Creek that reflect conditions prior to the baseline monitoring program, historic flow conditions of the stream must be estimated. The precipitation measured in the project area was near historic annual averages, as discussed previously, so it may be assumed that the flow measured in Evacuation Creek during the first year of monitoring was nearly average. If this is the case, several reaches of the stream are certain to be dry for extended periods in years when precipitation is below average.

Peak flows of streams in arid regions are difficult to estimate because the flows are directly related to runoff from rainfall, which is much more variable than runoff from snowmelt. There are several methods of using the general characteristics of a drainage basin to estimate peak flows. The Soil Conservation Service (SCS) has developed a method for estimating peak flows for various return periods from soil

and precipitation data. The results of this analysis for Evacuation Creek are shown on Table II-1. By the SCS method the estimated average daily peak flows for 2-year and 50-year return intervals are 7.0 m^3/s (247 cfs) and 28 m^3/s (987 cfs), respectively. Although peak flows can be estimated with these methods, considering the errors inherent in applying such general techniques to a specific area, these estimates may be accurate only within ±100 percent of the estimated value.

Besides the SCS method the USGS has developed two sets of equations to calculate peak flows by regression analysis. The first set of equations was developed on the basis of hydrologic areas in the United States using a comparison of mean precipitation, elevation, and annual flow to peak flows of various durations. The second set of equations, developed from data relevant to Colorado streams, included significant characteristics from a set of 11 possible variables.

In addition to flood-frequency analysis, the Utah Water Research Laboratory has developed a means of estimating the maximum probable floods on Utah streams. This method indicates that the maximum probable flood in Evacuation Creek is 1030 m^3/s (36,000 cfs).

First-Year Flows: During the 1975 water year, the approximate total volumes of water passing the gauges was 2140 ha-m (1610 acre-ft) at Station S-7, 1350 ha-m (1020 acre-ft) at Station S-6, and 1140 ha-m (860 acre-ft) at Station S-2. Flows decrease moving downstream, indicating that losses to evaporation and aquifers are not replaced by surface runoff or aquifer seepage. For the two gauges (stations S-8, S-15) on tributary canyons to Evacuation Creek, no flow was measured at any time during the year. The flow pattern within the year for the three gauges on Evacuation Creek are shown on figures II-15 through II-17. The short duration but intense flows of surface runoff metnioned earlier are evident in these figures. The relationships of water temperature and specific conductance to streamflow noted in the White River also apply to Evacuation Creek.

During the first year of monitoring, the maximum mean daily streamflow observed in Evacuation Creek was 2.0 m^3/s 71 cfs) on May 28. This is probably not unusual, since the instantaneous peak flow on this day was 7.1 m^3/s (250 cfs) at Station S-2, which from the estimated peak flows has a return interval of about 2 years. Flows were occasionally less than 0.0003 m^3/s (0.01 cfs), effectively 0.0 for several days during August.

TABLE II-1

ESTIMATED PEAK STREAMFLOWS FOR
EVACUATION CREEK
m^3/s (cfs)

Method	Return Period					
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
USGS[1]	9.6 (340)	18 (650)	25 (870)	38 (1330)	48 (1710)	
USGS[2]	11 (404)	20 (711)	26 (935)	34 (1250)		
SCS	8.2 (290)	37 (1300)	53 (1870)	90 (3170)	118 (4180)	154 (5440)

[1]Regional Drainage Method

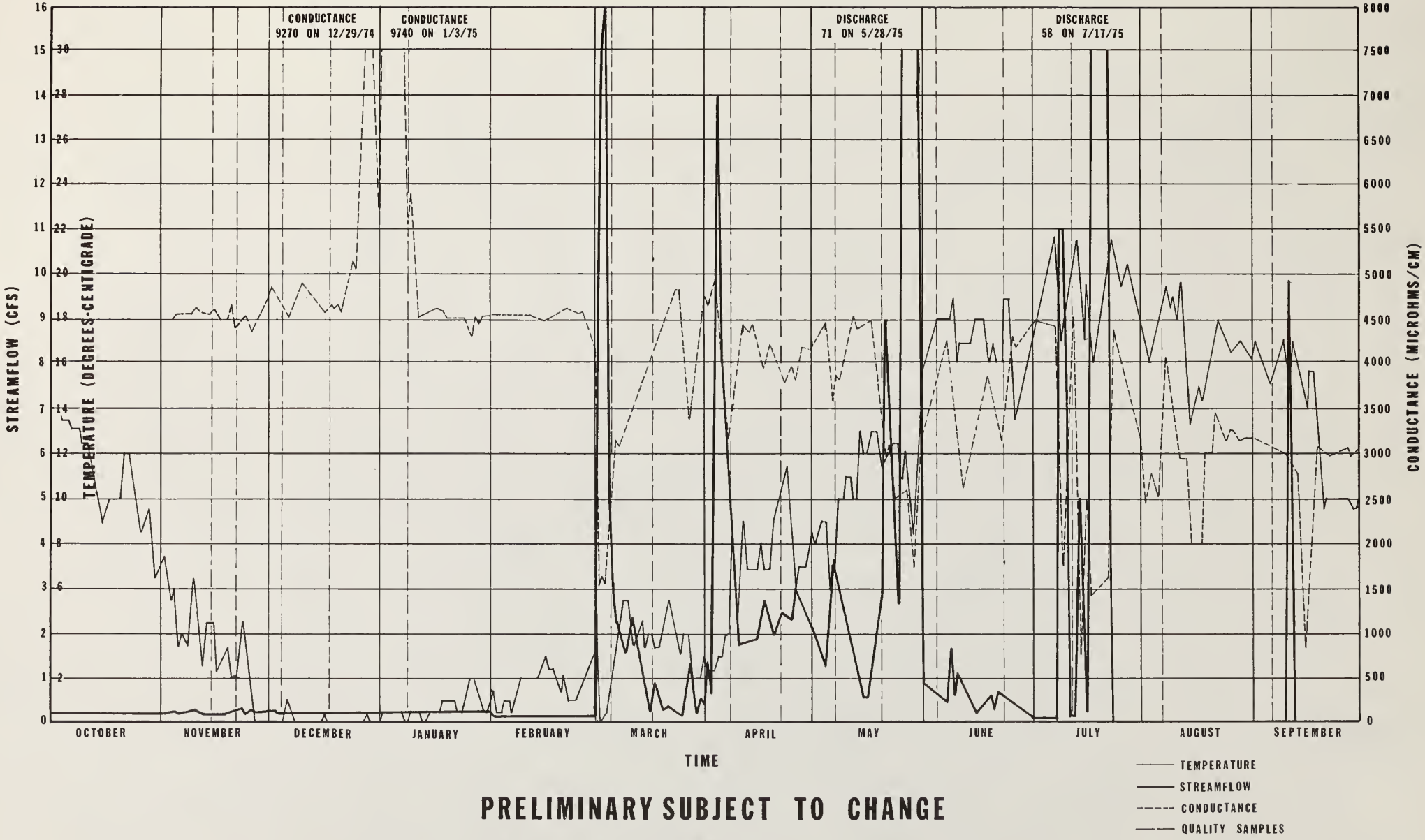
[2]General Characteristic Method

The peak flows usually relate rainfall periods within the study area, but not all rainfall periods correlate with high flows. Because the study area contains only a portion of the Evacuation Creek basin and contributes so little to flow in Evacuation Creek, rainfall in the study area and high flows in Evacuation Creek correlate only when storms cover the entire drainage.

Runoff from snowmelt contributed to flow only during the first part of March. This volume of water was considerably less than the annual snowfall would indicate, since most was returned to the atmosphere through sublimation of the snow crystals or evaporation of the melted snow or was lost to the ground as soil moisture or aquifer recharge. Rainfall, on the other hand, came mainly from brief, intense thundershowers that quickly saturated the ground surface and produced runoff.

First-Year Flow Patterns: Flow within Evacuation Creek is complex and not yet completely understood, making comparisons between the gauges difficult. Unlike the White River, surface runoff contributes substantial amounts of water to the creek. The surface runoff is of short duration but very intense, and consequently between 60 percent and 90 percent of the total flow in Evacuation Creek during the first year was surface runoff. (In the White River, only between 40 percent and 60 percent of the yearly flow is directly attributable to surface runoff.) Ground water seepage is a minor but consistent fraction of the flow in Evacuation Creek, with flow measured at all three gauges for all but a few days of the year.

As will be discussed, the chemical-quality samples collected at the gauge locations are so similar that flow must be fairly continuous between the stations, although some intermediate stream sections appear to be dry. In these dry sections flow continues through other means, such as the stream alluvium or the bird's nest aquifer where it contacts the stream. The gauges were placed at points where some of the water flowing in the alluvium is forced to the surface so that the gauges measure both the surface flow and the alluvial flow. In the section between stations S-7 and S-6, the surface is occasionally dry, but it is assumed that flow continues in the alluvium. Between stations S-6 and S-2 it is possible that both the surface and the alluvium are occasionally dry but that flow continues through the bird's nest aquifer.



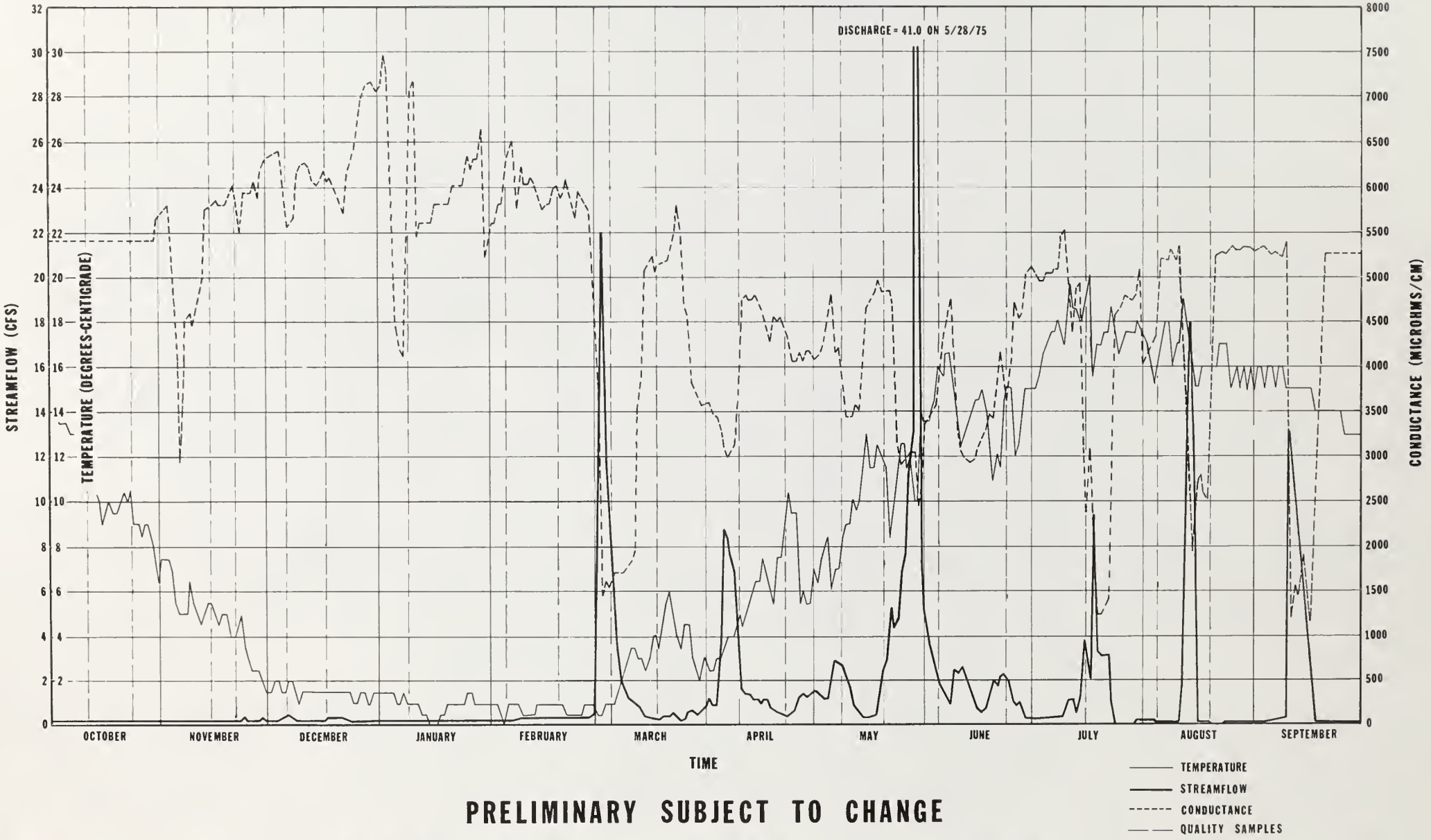
PRELIMINARY SUBJECT TO CHANGE

MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

EVACUATION CREEK BELOW PARK CANYON NEAR WATSON, UTAH - (S-7)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-15



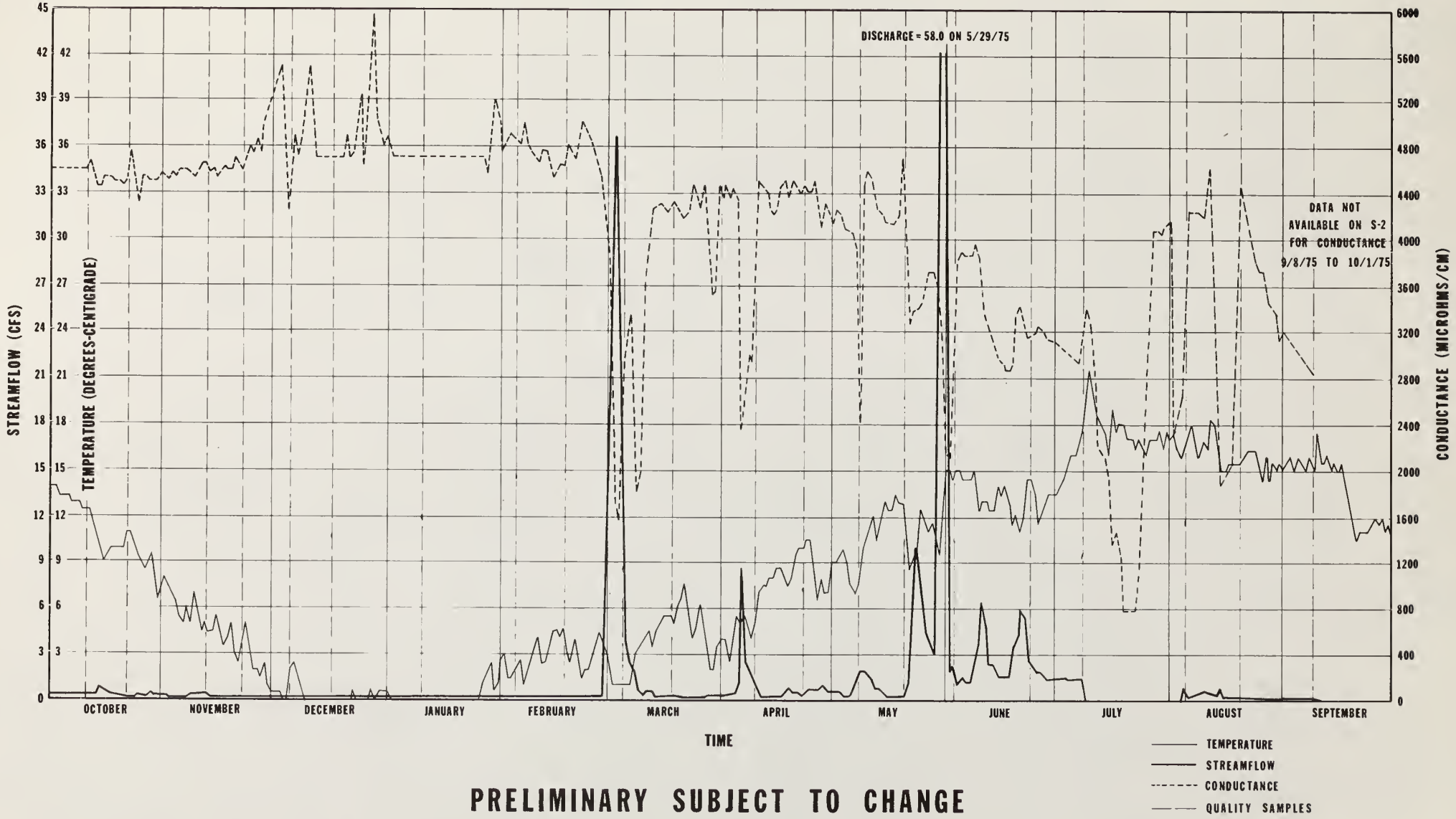
PRELIMINARY SUBJECT TO CHANGE

MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

EVACUATION CREEK AT WATSON, UTAH - (S-6)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-16



PRELIMINARY SUBJECT TO CHANGE

MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE

EVACUATION CREEK NEAR MOUTH BELOW WATSON, UTAH - (S-2)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-17

The Washes--Southam Canyon, Hells Hole Canyon, and Asphalt Wash: Southam Canyon, Hells Hole Canyon, and Asphalt Wash are similar drainages in that they flow irregularly and briefly. Southam Canyon is the most relevant to the study since about 13 km^2 (5 sq mi) of its 23-km^2 (9 sq mi) drainage area is within Tract U-a. The drainage area of Asphalt Wash is about 264 km^2 (100 sq mi), about 2.5 km^2 (1 sq mi) of which is within Tract U-a. Hells Hole Canyon drains about 70 km^2 (26 sq mi), none of which is within either tract.

Several gauging stations established for the baseline program measure streamflow within these washes. One station is at the mouth of Hells Hole Canyon (S-5), and stations are upstream and downstream of the affected areas on Southam Canyon (S-9 and S-13) and Asphalt Wash (S-10 and S-12). The flows measured at these stations are summarized on Table II-2.

During the 1975 water year the total flows from these canyons were 370 ha-m (280 acre-ft) from Hells Hole Canyon, 28 ha-m (21 acre-ft) from Southam Canyon, and 22 ha-m (17 acre-ft) from Asphalt Wash. Except for Hells Hole Canyon these total flows are below the estimated average annual yields shown in Table II-3. Together, these figures indicate an annual runoff rate of 0.182 ha-m/km^2 (2.36 acre-ft/sq mi). A comparison of these figures and 49 ha-m/km^2 (640 acre-ft/sq mi), the estimated average precipitation, demonstrates that only about 0.4 percent of the precipitation became runoff.

Since Southam Canyon drains most of Tract U-b, an estimated water balance was calculated for the 1975 water year. Table II-4 lists the total runoff, precipitation, and evapotranspiration in Southam Canyon's tributary area within the tracts. The average annual precipitation recorded in 1975-- 25.02 cm (9.85 in.)-- equalled the long-term regional record of the area (Figure II-3), and the winter and summer precipitation corresponded with the long-term records (Figure II-5, II-6); thus precipitation within the canyon was average in 1975. As seen in Table II-4, 100 percent of the water falling from May 1975 through September 1975 and 98.8 percent of the water falling from October 1974 through April 1975 was lost through evapotranspiration. The rainfall intensities recorded during the 1975 water year were light-- almost 50 percent of all storms resulted in less than 0.8 cm (0.30 in.) of precipitation.

The potential evaporation from May through September 1975 was 69.73 cm (27.45 in.), which corresponds closely with the seasonal consumptive-use factors for the region (Austin and Skogerboe 1970). The total potential evapotranspiration was estimated by multiplying the seasonal consumptive-use factor by the crop-use coefficient (k=0.5 to 0.8 for native vegetation, depending upon the month analyzed). The difference

TABLE II-2

HELLS HOLE CANYON, SOUTHAM CANYON, AND ASPHALT WASH STREAMFLOW RECORDS
m^3/s (cfs)

STATION		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
S-5 Hells Hole Canyon	Number of Days of Flow	0	0	0	0	1	2	0	1	0	2	4	
	Mean Daily Flow During Event	-	-	-	-	0.195 (6.9)	0.075 (2.66)	-	0.059 (2.1)	-	0.022 (.076)	0.023 (.082)	
S-9 Southam Canyon	Number of Days of Flow	0	0	0	0	1	1	0	0	0	0	0	
	Mean Daily Flow During Event	-	-	-	-	0.014 (.49)	0.008 (.28)	-	-	-	-	-	
S-13 Southam Canyon At Mouth	Number of Days of Flow	0	0	0	0	1	2	1	0	0	0	0	
	Mean Daily Flow During Event	-	-	-	-	0.134 (4.7)	0.083 (2.9)	0.001 (0.02)	-	-	-	-	
S-10 Asphalt Wash	Number of Days of Flow	0	0	0	0	2	0	0	0	0	1	1	
	Mean Daily Flow During Event	-	-	-	-	0.044 (1.56)	-	-	-	-	0.037 (1.30)	0.002 (0.06)	
S-12 Asphalt Wash At Mouth	Number of Days of Flow	0	0	0	0	0	1	0	0	0	2	4	
	Mean Daily Flow During Event	-	-	-	-	-	0.007 (0.23)	-	-	-	0.070 (2.49)	0.068 (2.40)	

TABLE II-3

ANNUAL RUNOFF ESTIMATES

	Area (SqMi)	Average Annual Runoff (acre-feet) 1962-1974
White River Below Meeker, Colo.	1040	455,000
White River at Watson, Utah	4020	482,400
Increase	2980	27,400
Piceance Creek* at White River	659	15,150*
Remaining Watershed Between Meeker & Watson less Piceance Creek	2351	12,250

*Extrapolated from 1965-66, 1971-74 data

Basin	Areal % of Remaining Watershed	Estimated Average Annual Runoff (acre-feet)
Hells Hole Canyon	1.11	135
Evacuation Creek	12.1	1480
Southam Canyon	0.36	45
Asphalt Wash	4.25	520

TABLE II-4

WATER BALANCE-WY 1975
SOUTHAM CANYON
(Within Tract)
cm (In.)

Time Period	Average Precipi-tation	Total Runoff	Soil Storage Change *	Total Evapo-trans-piration	Percent Evapo-trans-piration	Pan Evapo-ration	Pan Coefficient **	Potential Evaporation ***
Oct. 1974 through April 1975	12.67 (4.99)	0.15 (0.06)	0 (0)	12.52 (4.93)	98.9%			
May 1975 through Sept. 1975	12.34 (4.86)	0 (0)	0 (0)	12.34 (4.86)	100.0%	99.62 (39.22)	0.70	69.73 (27.45)
Oct. 1974 through Sept. 1975	25.02 (9.85)	0.15 (0.06)	0 (0)	24.87 (9.79)	99.4%			

* Assumed to be in static condition or zero change
** Average coefficient suggested by Vente Chow: "Handbook of Applied Hydrology" to account for radiation effects on Pan
*** Potential free surface evaporation which is comparable to the potential consumptive use factor

between the actual and the potential evapotranspiration represents the water deficit, which from May 1975 through September 1975 ranged from 22.5 cm (8.9 in.) to 43.4 cm (17.1 in.).

The USGS is updating and revising the runoff-flow data for Hells Hole Canyon and Asphalt Wash. The water balance cannot be accurately assessed until the data are finalized. The percentage of evapotranspiration to precipitation should be similar to that of Southam Canyon.

Peak flows in the dry washes were estimated by the same method used for Evacuation Creek. The results of the analysis are shown in Table II-5. The wide variations in the values indicate that the figures must be used with caution.

The estimated maximum probable floods for the washes are 370 m^3/s (13,000 cfs) in Hells Hole Canyon, 230 m^3/s (8,000 cfs) in Southam Canyon, and 660 m^3/s (23,000 cfs) in Asphalt Wash. No unusually high flows were encountered during the 1975 water year: the maximum instantaneous peak flows calculated from high-water marks were 8.1 m^3/s (287 cfs) in Hells Hole Canyon and 0.08 m^3/s (2.7 cfs) in Southam Canyon.

b. Summary of Water Quality

Water quality constituents are of two broad classes: materials suspended in water and elements dissolved in water. The suspended matter consists of soil, forest detritus, and rock fragments washed into the stream by rain or snowmelt. The size of the particles range from microscopic grains to rocks, but most of the material will be between 0.001 mm and 10 mm in diameter and will come from soil erosion. The finest particles can remain suspended even in quiescent water, but the larger particles will settle unless the water is turbulent. Since velocity and turbulence vary throughout the cross section of a stream, the suspended matter, usually referred to as suspended sediment, also varies with position in the stream; consequently, a composite sample collected from throughout the stream cross section is the only true representation of the stream's suspended sediment content.

Besides the stream itself, the streambed is also a source of useful information about the sediment carried by the stream, because the streambed is composed of material that has settled from the stream or is being pushed or rolled along the streambed.

Elements are dissolved in water in several ways. First, rainfall forms a weak solution of carbonic acid by combining with carbon dioxide in the atmosphere. This solution dissolves elements not otherwise soluble. Second, water alone is a

TABLE II-5

ESTIMATED PEAK STREAMFLOWS FOR
HELLS HOLE CANYON, SOUTHAM CANYON, AND ASPHALT WASH
m^3/s (cfs)

Drainage	Method	2 Yr	5 Yr	10 Yr	25 Yr	50 yr	100 Yr
Hells Hole Canyon	USGS[1]	1.6 (55)	2.8 (100)	4.0 (140)	5.9 (210)	7.6 (270)	
	USGS[2]	1.3 (47)	2.5 (87)	3.3 (116)	3.9 (137)		
	SCS*	3.2 (115)	2.6 (924)	40 (400)	46 (1600)	58 (2100)	70 (2500)
Southam Canyon	USGS[1]	0.6 (21)	1.1 (39)	1.6 (55)	2.2 (80)	3.0 (105)	
	USGS[2]	0.3 (12)	.7 (25)	1.1 (38)	1.2 (41)		
	SCS	1.1 (40)	9.1 (320)	14 (480)	16 (560)	20 (720)	24 (850)
Asphalt Wash	USGS[1]	4.0 (140)	6.8 (240)	10 (360)	15 (540)	19.8 (700)	
	USGS[2]	4.0 (140)	7.5 (263)	10 (360)	12 (470)		
	SCS*	12 (400)	100 (3600)	155 (5300)	180 (6200)	220 (8000)	270 (9000)

*SCS Method Modified for Limited Data

[1]Regional Drainage Method

[2]General Characteristic Method

strong solvent that over time will dissolve even resistent materials such as glass. Compounds such as halite (table salt) dissolve almost immediately, while other less soluble compounds, such as limestone, dissolve more slowly and are gradually carried away. Some rock materials, like granite, are nearly insoluble and are broken down mainly through physical action over long periods of time. Third, water as a medium mixes elements and promotes reactions that would not otherwise occur; it also promotes the use and exchange of dissolved and suspended material through growth and decay of organic matter.

Dissolved elements, like streamflow, have two distinct yearly periods, baseflow and highflow. Concentrations of dissolved solids are highest during low streamflow, when ground water seepage is a major portion of streamflow. Ground water moves slowly through the soil and rock, which allows longer contact with minerals, so that more are dissolved. In the study area, concentrations of dissolved solids are usually highest in fall and winter, lasting from August through February.

Historic Water Quality

Historic water quality data for the study area are available only for Station S-3 on the White River from 1951 to the present. No known samples had been taken from Evacuation Creek, Hells Hole Canyon, Southam Canyon, or Asphalt Wash prior to the baseline study. The historic mean monthly concentrations for constituents tested for samples from Station S-3 are shown on figures II-18 and II-19.

First-Year Water Quality: White River

As discussed in the hydrology section, the White River passes through the project area but gains so little flow within the tract area that changes in the river as a result of inflow are difficult to discern. Figures II-20 and II-21 show the seasonal variation of the general water quality characteristics throughout the study area during the first year of monitoring. (The two monitoring stations used in the plot--S-1 and S-11--represent the uppermost the lowermost baseline stations on the White River.) The three characteristics shown in the plot are dissolved solids, suspended sediment, and pH. These describe the suspended material in the water, the dissolved elements in the water, and the chemical balance of the water, respectively. The time scale on these and later figures coincides with that used in the previous hydrographs for easy comparison of streamflow and water quality.

As expected, dissolved solids in the White River are highest during low streamflow and decrease with increasing streamflow. The average level of dissolved solids in June was 262 mg/l--less than half that found between August and April (561 mg/l). May and July are transition months during which the flow, and thus the dissolved solids concentrations, changes rapidly. The dissolved-solids concentrations for August (when the river returns to baseflow) through January were similar to those recorded before the high-flow period. During the baseflow period, the dissolved solids gradually increase, although streamflow is relatively stable during this same period. The differences between the levels at stations S-1 and S-11 are very slight, and therefore the levels of dissolved solids increase very little across the project area. From August through May the dissolved-solids concentrations exceeded 500 mg/l, the tolerance level for sensitive crops, but never exceeded 1000 mg/l, the tolerance level for less sensitive crops (NAS 1972).

Suspended-sediment concentrations are generally directly related to streamflow. During winter, sediment levels remain low because very little surface runoff contributes to the stream. Between March and April, sediment concentration increases as the result of runoff from snowmelt in the lower elevations of the basin. The highest sustained sediment concentrations occur between May and July, coinciding with the high stream flows that results from melting of the upper basin snowpack. The occasional high-sediment concentrations in August and September are probably caused by intense thunderstorms in the lower basin. Suspended sediment concentrations are so highly variable--often by a factor of 100 or more within hours or sometimes minutes--that it is difficult to assess changes in concentration across the study area. It may be surmised that the changes in suspended-sediment levels between the upper and lower stations are indicative of what actually occurred (Figure II-20).

The pH is directly related to the hydrogen low concentration in the water but is most useful in indicating whether the water is alkaline or acidic. The pH values of the White River are consistently slightly alkaline and do not change between the highflow and baseflow periods. The pH values on the White River also do not change between the upper and lower stations in the study area. This slightly alkaline condition is typical of streams in the western United States. In terms of water quality criteria, the pH is within the accepted range of 6 to 9 units, which is considered suitable for all uses (NAS, 1972).

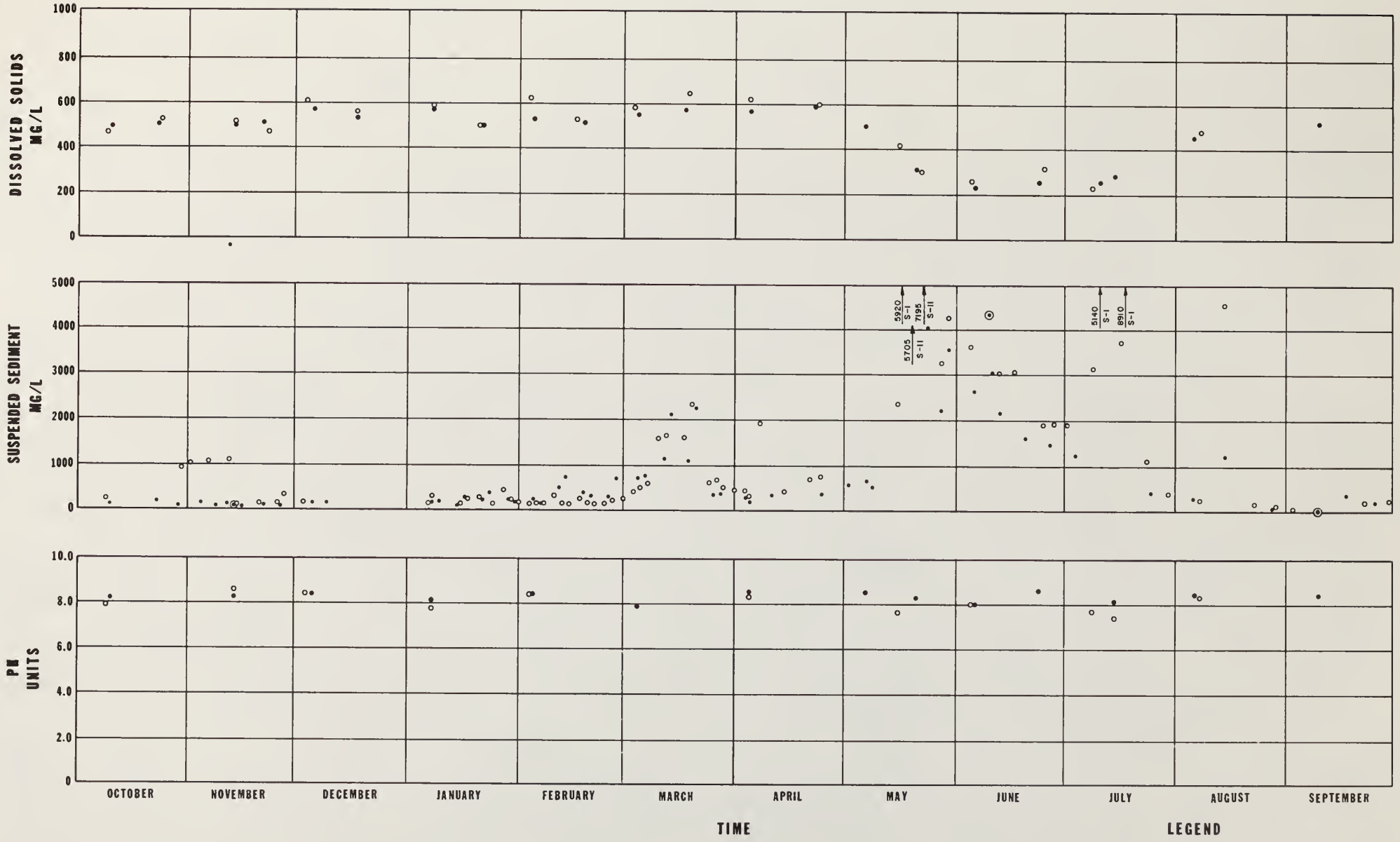
CFS X 100
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE JULY AUG. SEPT.
30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
MILLIGRAM/LITER (M/L) X 10
LEGEND
--- CARBONATE
// BICARBONATE
≡ CHLORIDE
— FLORIDE, LESS THAN ONE.
NITRATE, LESS THAN ONE.
PHOSPHATE, LESS THAN ONE.
— MEAN STREAM DISCHARGE

GENERAL WATER QUALITY
WHITE RIVER : WATSON (9-6500)

FIGURE II-18

GENERAL WATER QUALITY
WHITE RIVER : WATSON (9-6500)

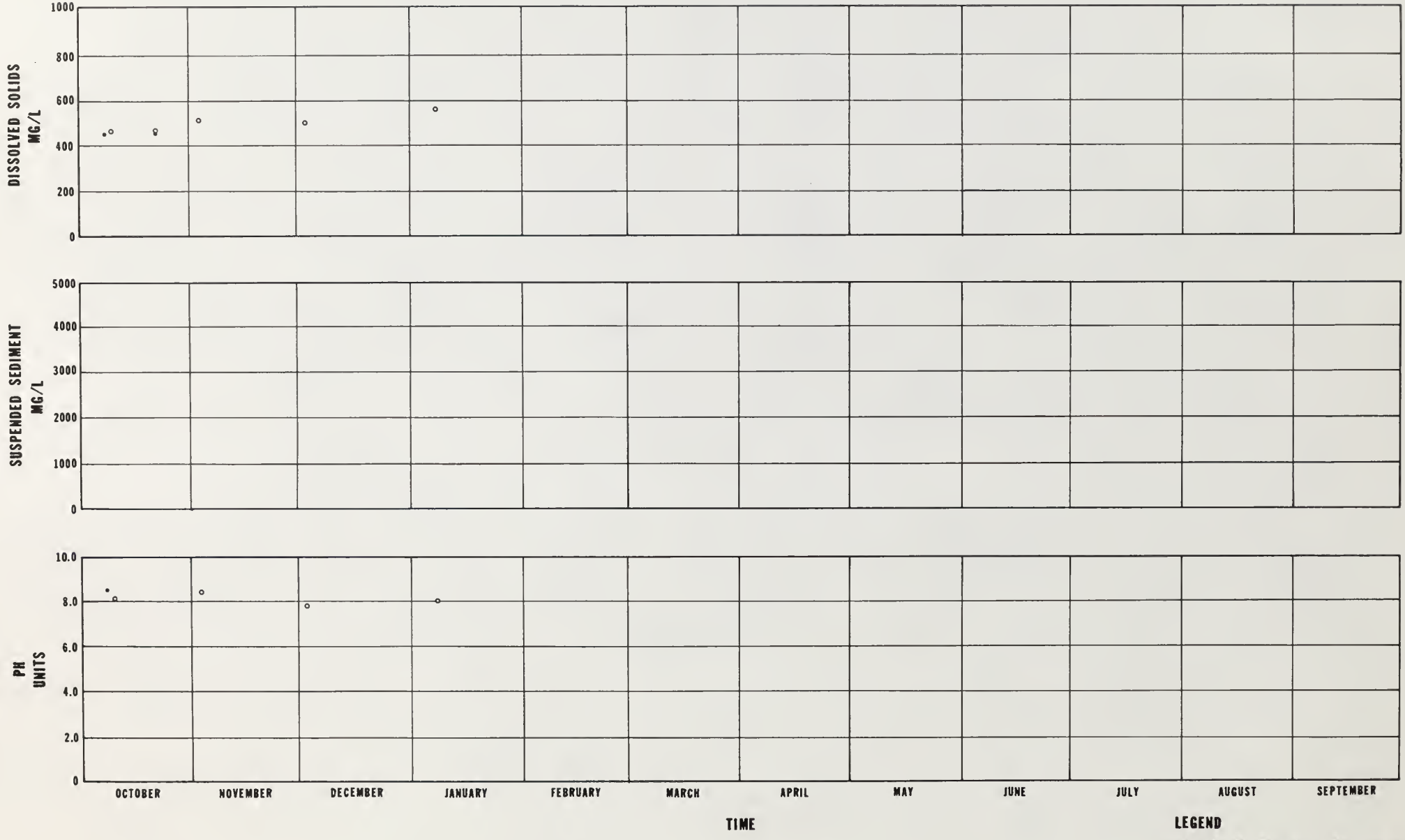
FIGURE II-19



VARIATION OF GENERAL CHARACTERISTICS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-20



VARIATION OF GENERAL CHARACTERISTICS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-21

Major Dissolved Elements - Cations: The concentration of an element in natural water is dependent upon the abundance of its occurrence in nature and its ability to dissociate from its chemical bond. Once in solution, the ion will have mobility and may react to form a precipitate, react to change its valence, or enter into exchange reactions with minerals in suspension or in streambed. As the water moves, it mixes with other waters and passes through many types of environments. By the time a sizable stream is formed, the chemical balance in the water is such that dissolved elements are likely to remain dissolved.

In general, calcium, magnesium, sodium, and potassium form more than 90 percent of the cations (positive charges) present in surface water (Figure II-19). In the White River, calcium, magnesium, and sodium are the dominant cations (Figure II-22); potassium, however, is present in lesser concentrations (less than 10 mg/1). Calcium concentrations in the White River through January 1976 are shown in figures II-22 and II-23. During the baseflow period, concentrations were usually between 60 mg/1 and 80 mg/1. During December and early January 1975 and again in April 1975 calcium levels were at their highest. The December-January period coincides with the period of lowest flow in the river, while the April period is an average baseflow condition that occurs after increased streamflow from snowmelt in the lower basin during March. Throughout the period of record, differences between the two stations were slight, with no noticeable increase in calcium across the project area.

Magnesium concentrations are lower than those of calcium (figures II-22 and II-23). Baseflow concentrations of magnesium are about 30 mg/1, and highflow concentrations are only about half that amount. Variations in magnesium followed the same trend noted for calcium. No difference in magnesium concentration is descernible between stations S-1 and S-11 during the year.

Sodium concentrations ranged from 60 mg/1 to 90 mg/1 during baseflow and were 30 mg/1 or less during highflow (figures II-22 and II-23). Sodium concentrations varied more with streamflow than did either magnesium or calcium. The concentrations of sodium appear to be much higher in the ground water than in the surface runoff, meaning that sodium levels are more sensitive to changes in the ratio between surface runoff and ground water in streamflow than are either calcium or magnesium.

Potassium concentrations varied like the other elements. Concentrations were about 2.4 mg/1 during baseflow and about 1.6 mg/1 during highflow. Again, there was no discernible difference between concentrations at stations S-1 and S-11.

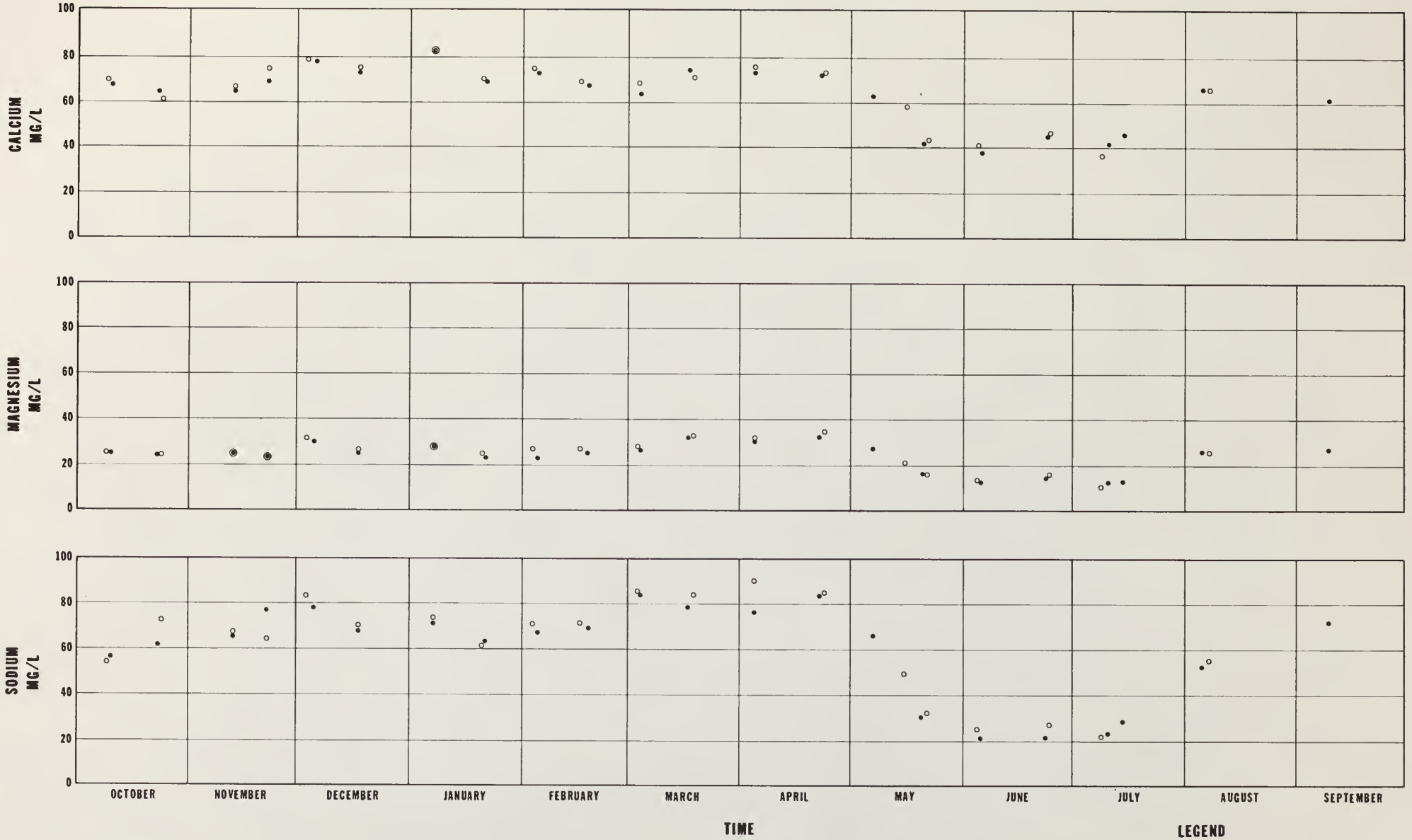
Calcium, magnesium, sodium, and potassium all showed similar trends during the 1975 water year and seem to be following nearly identical trends through January 1976. Variations seem to be directly related to changes in the proportion of ground water seepage to surface runoff. Calcium, magnesium, sodium, and potassium trends also vary in response to changes in the proportion of upper-basin to lower-basin ground water in the total streamflow. It is this upper-basin to lower-basin ratio that causes the higher concentrations in these elements in April. During this time, the poorer quality ground water from the lower basin in contributing more water to the stream than at any other time of the year.

Although there are no water-quality standards for any of these elements individually, the presence of sodium in water can be a factor in decreasing land productivity if this water is used for irrigation. The sodium absorption ratio (SAR), which relates the sodium concentration to those of calcium and magnesium combined, is used to measure the potential for ion exchange reactions. The SAR varied from about 2 during baseflow to about 1 at highflow. An older measure of ion exchange potential is the percentage of sodium, which indicates the proportion of sodium in the cations. In the White River, the percent sodium level varied from an average of 36 percent during baseflow to about 25 percent during highflow. Neither criteria indicates problems in using the White River for irrigation.

The hardness of water, a measure of its comsumption of soap, relates directly to the sum of the concentrations of calcium and magnesium. Hardness levels in the White River ranged from about 290 mg/l (very hard) during baseflow to about 170 mg/l (hard) during highflow.

Major Dissolved Elements - Anions: In the White River, the anions (negative charge) are mostly bicarbonate, sulfate, and chloride. Fluoride, bromide, sulfide, nitrate, and phosphate are also present but in much lesser quantities.

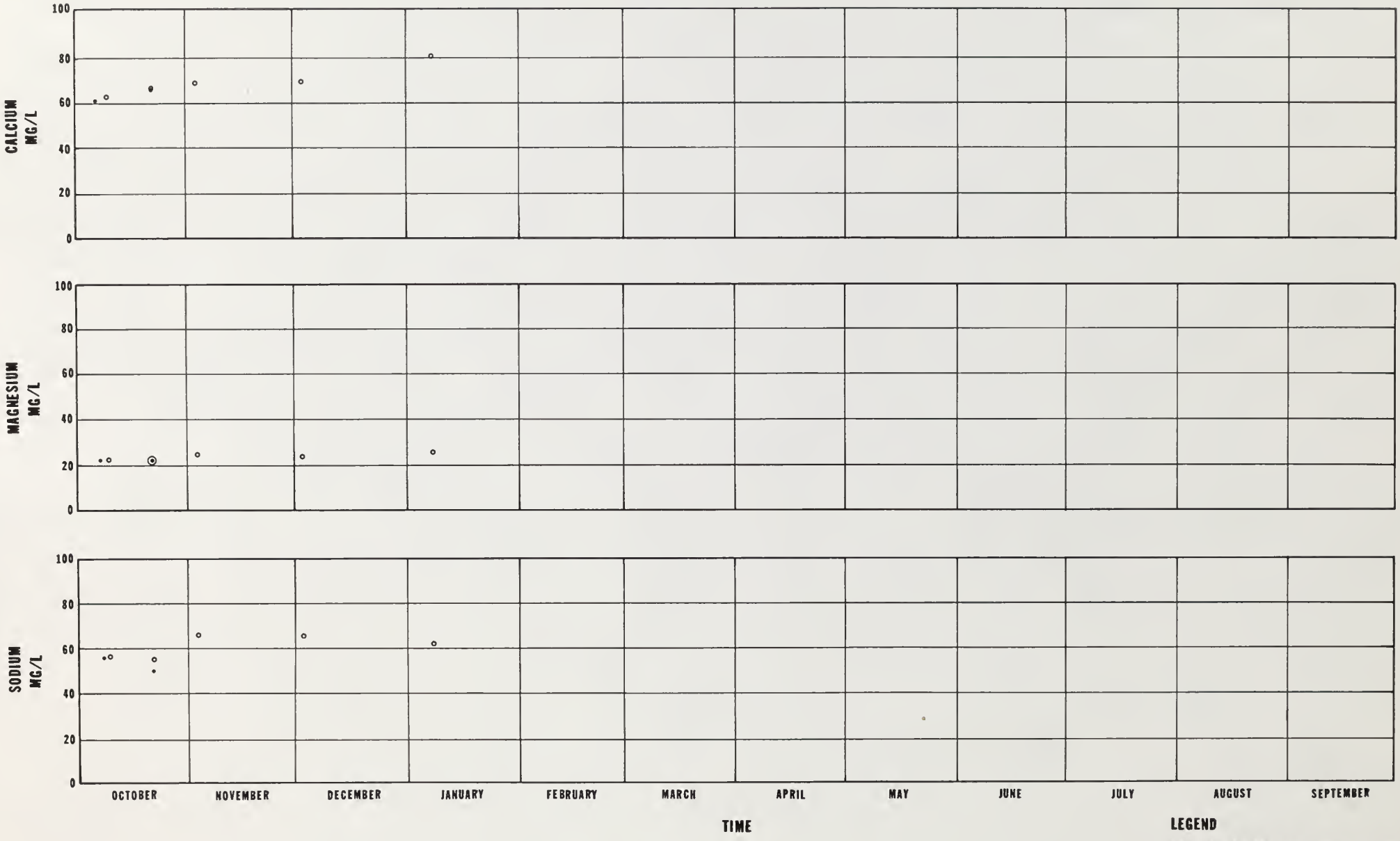
Bicarbonate is somewhat unusual in that it enters solution from two very different sources: chemical and physical. Chemical sources of the bicarbonate ion include the dissolving of carbonate or bicarbonate minerals in water and the production of carbonate or bicarbonate ions as the byproduct of chemical reactions. The physical source of carbonate and bicarbonate ions--the principal source of these ions--is dependent on the presence of carbon dioxide. Carbon dioxide is absorbed into water either by the absorption of atmospheric carbon dioxide or from algal respiration in the water. Carbon acid (H_2CO_3) is then formed which dissociated into hydrogen ions and either carbonate or bicarbonate ions, depending on the pH. As shown on figures II-24 and II-25, bicarbonate



VARIATION IN TIME OF MAJOR CATIONS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1974 - SEPTEMBER 1975

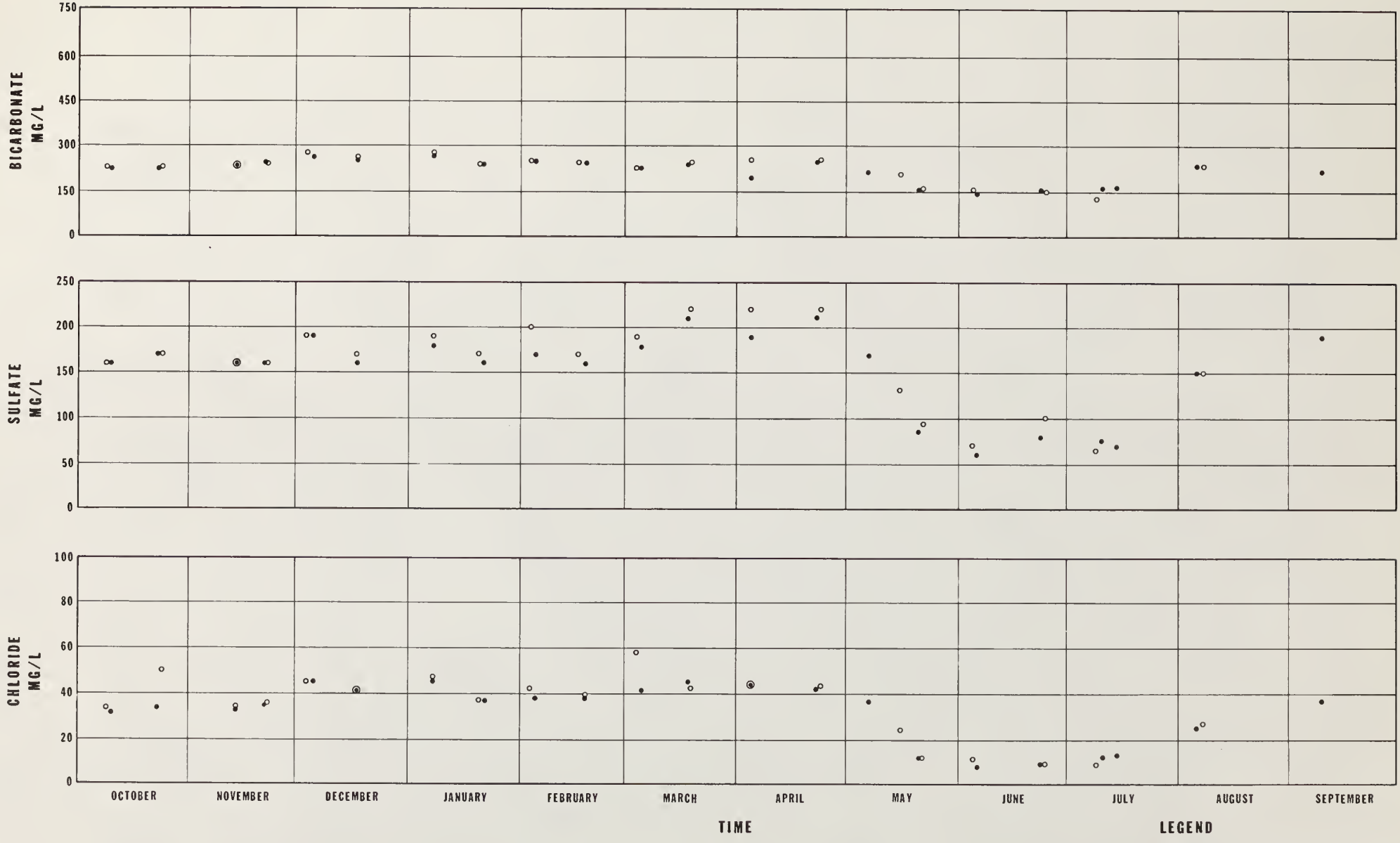
FIGURE II-22



VARIATION IN TIME OF MAJOR CATIONS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1975 - SEPTEMBER 1976

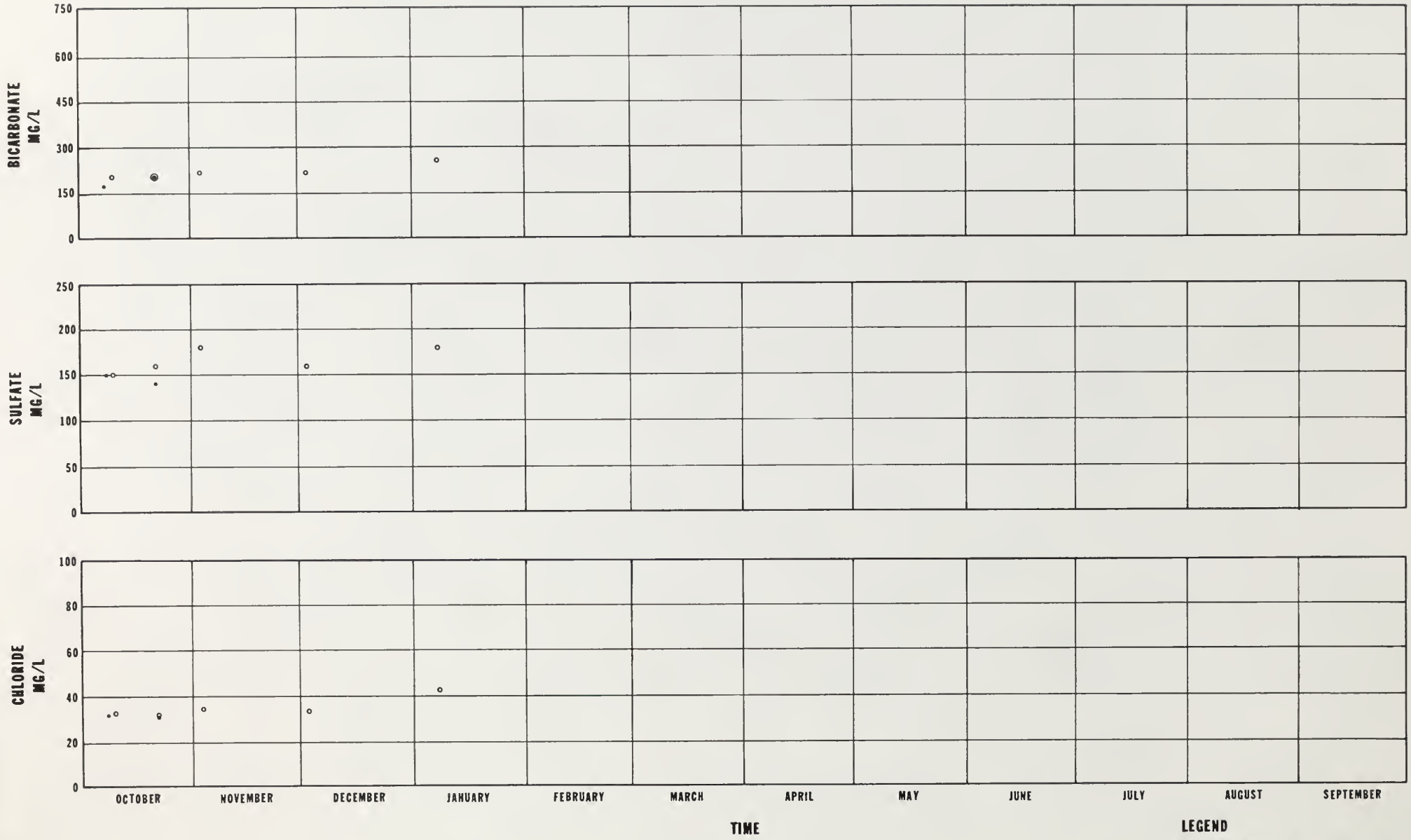
FIGURE II-23



VARIATION IN TIME OF MAJOR ANIONS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-24



VARIATION IN TIME OF MAJOR ANIONS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-25

concentrations are relatively constant with the time and flow. Besides remaining relatively constant, bicarbonate ions also act to buffer changes in the pH. Should an acid (i.e., hydrogen ions) be added to the water, bicarbonate ions will become bound. Until all the bicarbonate ions have reacted, the pH will remain relatively stable. If a base (i.e., hydrogen ion deficit) is added, the bicarbonate ions will dissociate to become carbonate and hydrogen ions, and again the pH will be changed only slightly. A stable pH means that the formation of precipitates from solution or dissolving of suspended sediment is unlikely; and since the data show that constituent concentrations vary only with changes in flow or biological phenomenon, it may be assumed that the system is in equilibrium. Also, since bicarbonate is absent from water with a pH of less than 9.0 and carbonic acid is absent in water with a pH of greater than 8.0, neither is present in the White River. Alkalinity is a measure of a solutions' ability to neutralize acid and is therefore closely related to the presence of bicarbonate ions. Alkalinity levels were correspondingly consistent, averaging between 130 mg/l and 200 mg/l.

Sulfate concentrations (figures II-24 and II-25) vary much like sodium concentrations. As minerals, most sulfur species are in the form of sulfides and sulfates. These minerals are either slightly soluble or they decompose by weathering on contact with water. In streams, most sulfur is present as sulfates, since sulfides oxidize to form sulfates. Dissolved-sulfur species are produced by leaching as water percolates through the strata; therefore, high sulfide and sulfate concentrations are characteristic of ground water seepage rather than of surface runoff. Sulfate concentrations in the White River ranged from around 180 mg/l during the baseflow period to about 80 mg/l during highflow. Sulfide was only about 0.2 mg/l and 0.05 mg/l during the same period. The wide range in concentrations is a further indication of the association of sulfate and sulfide ions and ground water. Sulfate shows about a 10 mg/l increase between stations S-1 and S-11 from December through April, suggesting the inflow of ground water to the White River, but differences between these stations are minimal at other times of the year. The concentrations are always below the 250 mg/l maximum for drinking water (USPHS, 1969) and should not restrict the use of the water for any purpose.

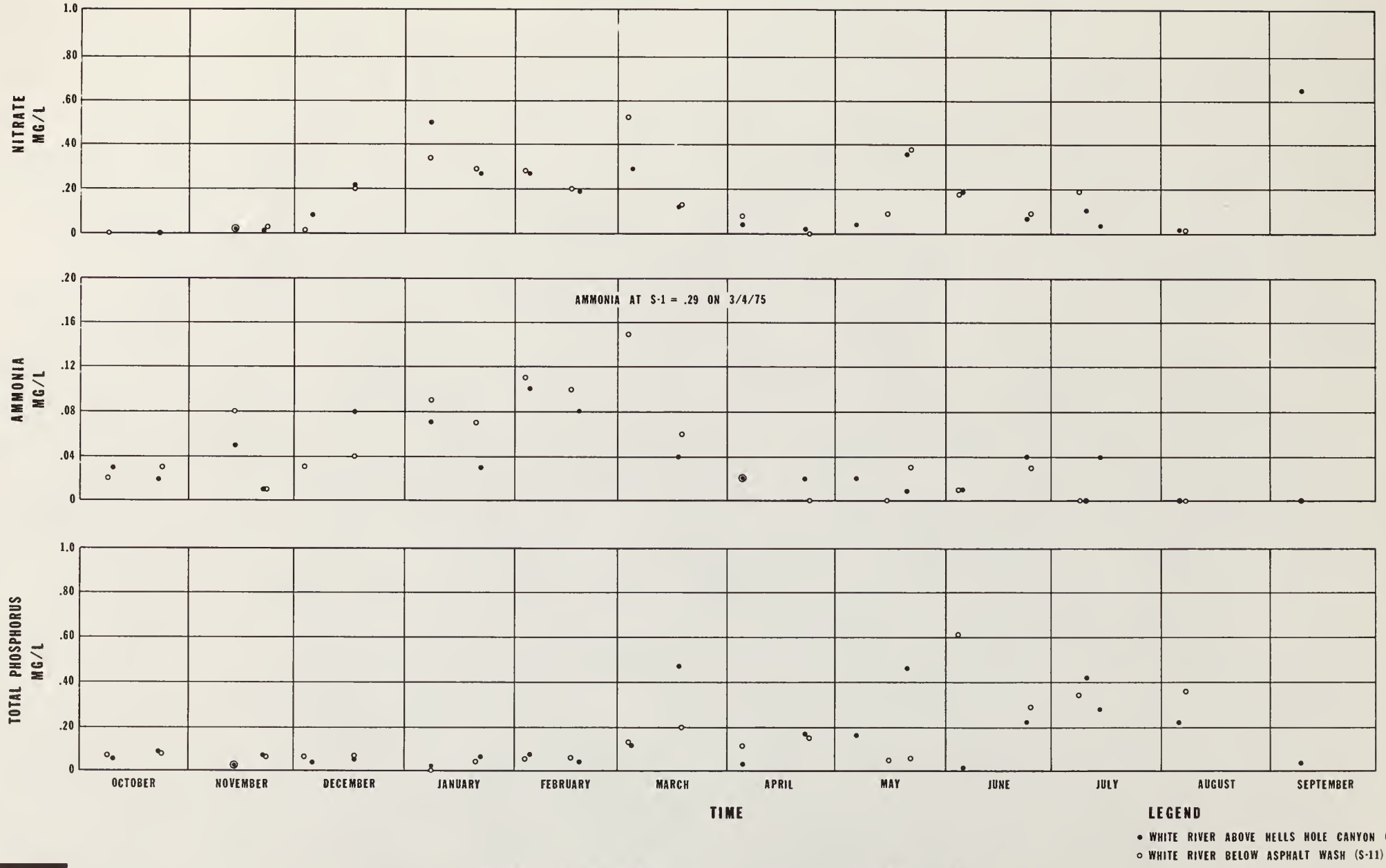
Like sodium, concentrations, chloride concentrations also vary during the year (figures II-24 and II-25), with maximum concentrations of about 40 mg/l during baseflow and only about 13 mg/l during highflow. The presence of chloride in water is not unexpected, since it is found in minerals in combination with potassium, sodium, and/or magnesium as highly soluble salts. Recommended concentrations are less than

100 mg/l in irrigation water (California Water Resources Control Board 1963). The concentrations of chloride in the White River exceeded none of these levels, so the presence fo chloride would not restrict use of the White River for these purposes.

Fluoride and bromide were both present in the White River in relatively low concentrations. Fluoride ranged from an average concentration of 0.3 mg/l during baseflow to 0.2 mg/l during highflow. On the average, bromide concentrations were 0.14 mg/l during baseflow and 0.05 mg/l during highflow. While there are no criteria for bromide, fluoride levels are important in water used for irrigation (1.0 mg/l, NAS 1972), livestock (2.0 mg/l, NAS 1972), and potable water supplies (0.7 mg/l, USPHS 1969). Since levels in the White River have never exceeded 0.4 mg/l, the water can be used for any of these purposes.

Variations in cation and anion concentrations in the White River during the baseflow may relate to differences between upper-basin and lower-basin aquifer quality. Of the three major ions that have varied significantly between high-flow and low-flow periods (sodium, sulfate, and chloride), sodium and sulfate concentrations have definitely increased in the river during March and April, the time that lower-basin aquifers would be recharged by the local March snomelt. Chloride has not increased during the same time period. Sodium and sulfate have shown high concentrations in the project area ground water samples, while chloride has not. Further, the variations between upstream and down-stream samples have been greater for sodium and sulfate than for calcium, magnesium, or chloride. Considering all this together, it is possible that sodium and sulfate are the dominate constituents in the lower-basin including the project area aquifers draining into the White River, and that calcium, magnesium, and chloride are the major elements in the upper-basin aquifers feeding the stream.

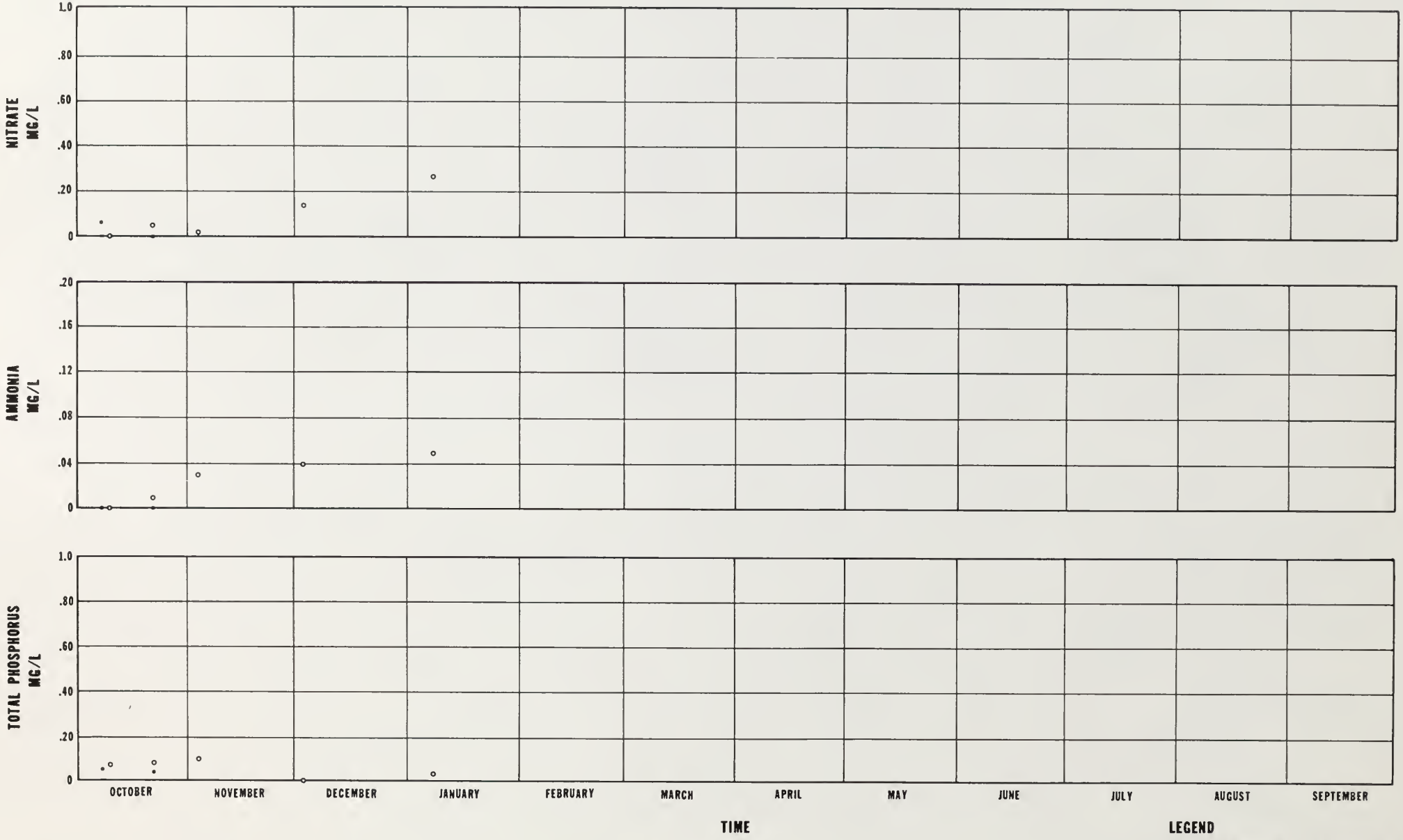
Nutrients: Nutrients are the constituents necessary to support life. The major nutrients in water are compounds of carbon, silica, nitrogen, and phosphorus. Since carbon and silica are usually present in such abundance that they exceed the requirements of the aquatic organisms, it is the amount of nitrogen and phosphorus compounds that controls growth. Phosphorus is found almost exclusively as phosphate, and nitrogen is usually found as either ammonia or nitrate (the oxidation of nitrite, an intermediate step between ammonia and nitrate, proceeds rapidly enough that nitrite is found only in low concentrations). Nitrate, ammonia, and phosphorus are necessary and controlling in aquatic life, but ammonia in high concentrations can be toxic to fish. (The concentrations of nitrate, ammonia, and phosphorus are given in figures II-26 and II-27.)



VARIATION IN TIME OF REPRESENTATIVE NUTRIENTS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-26



VARIATION IN TIME OF REPRESENTATIVE NUTRIENTS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1975 - SEPTEMBER 1976

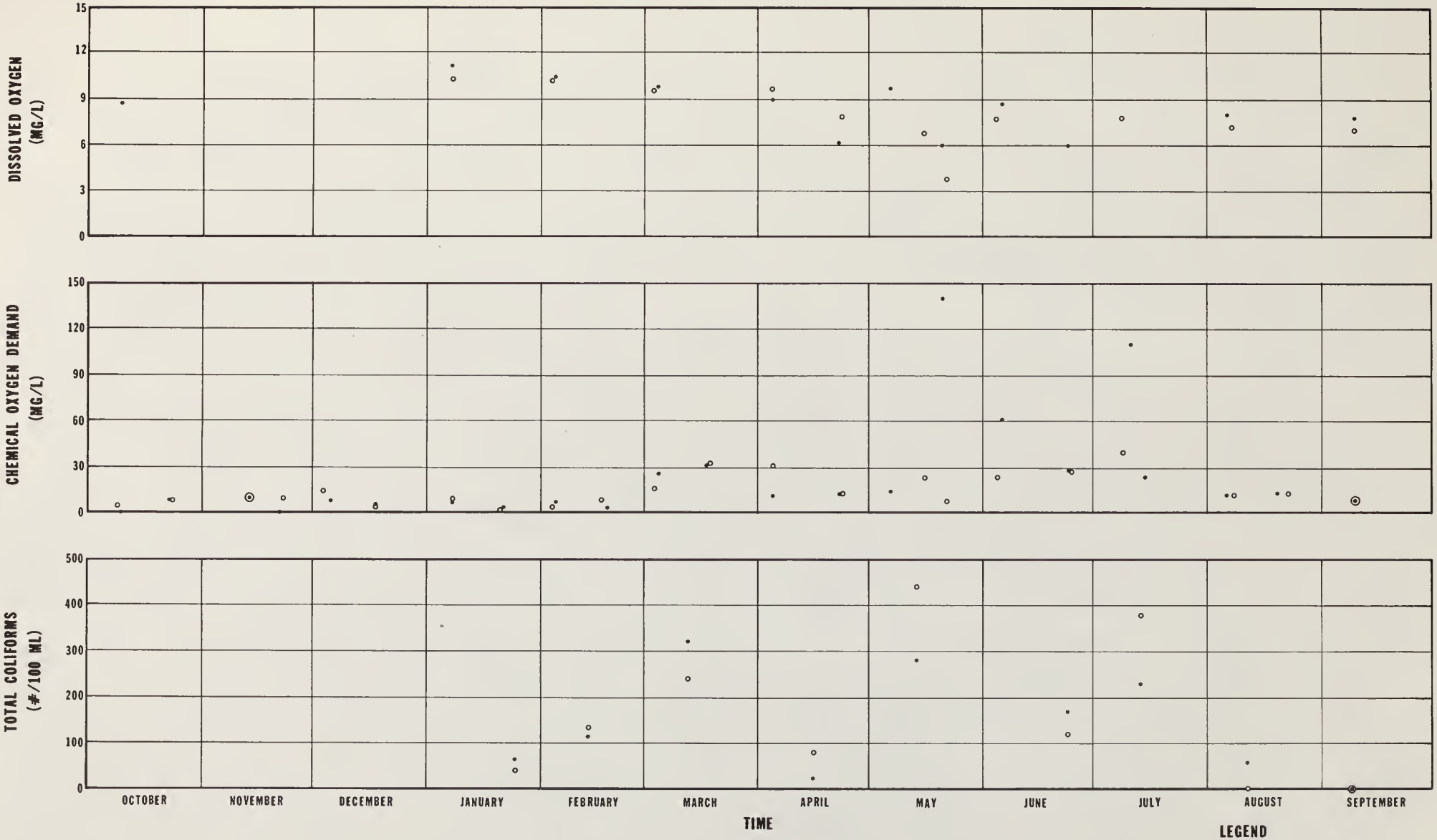
FIGURE II-27

Silica concentrations did not vary significantly with time or between stations. Levels were consistently near 13 mg/1. Carbon levels, as measured by total organic carbon (TOC) and total inorganic carbon (TIC) tests, followed expected trends. During baseflow the TOC was about 5 mg/1 and the TIC was nearly 30 mg/1, indicating that sufficient carbon is available for aquatic organisms. During high flow the TOC levels increased to between 9 mg/1 and 49 mg/1 among samples from the White River. These increases reflect not only increased aquatic growth, but also material carried to the stream by surface runoff.

In terms of standards, ammonia is the only nutrient with a direct adverse effect on aquatic life. Ammonia can be toxic to fish at levels in excess of 0.6 mg/1 for baseflow conditions or 0.5 mg/1 for highflow conditions (NAS 1972; EIFAC 1970). Neither criteria has been exceeded in samples from the White River.

Biochemical Constituents: Biochemical constituents are a link between the chemical (metals, nutrients, etc.) and biological (phytoplankton, algae, fish, etc.) aspects. The four constituents--dissolved oxygen, chemical oxygen demand, total coliforms (shown in figures II-28 and II-20), and chlorophyl A--are indicators of the relationship between chemical and biological processes. Dissolved oxygen is not only necessary for respiration by fish and algae, but is also a product of photosynthesis by algae and aquatic plants. Chemical oxygen demand is a measure of the oxidation capability of both chemical and biological constituents of the water. Coliforms are important as indicators of diseases that may be carried by water.

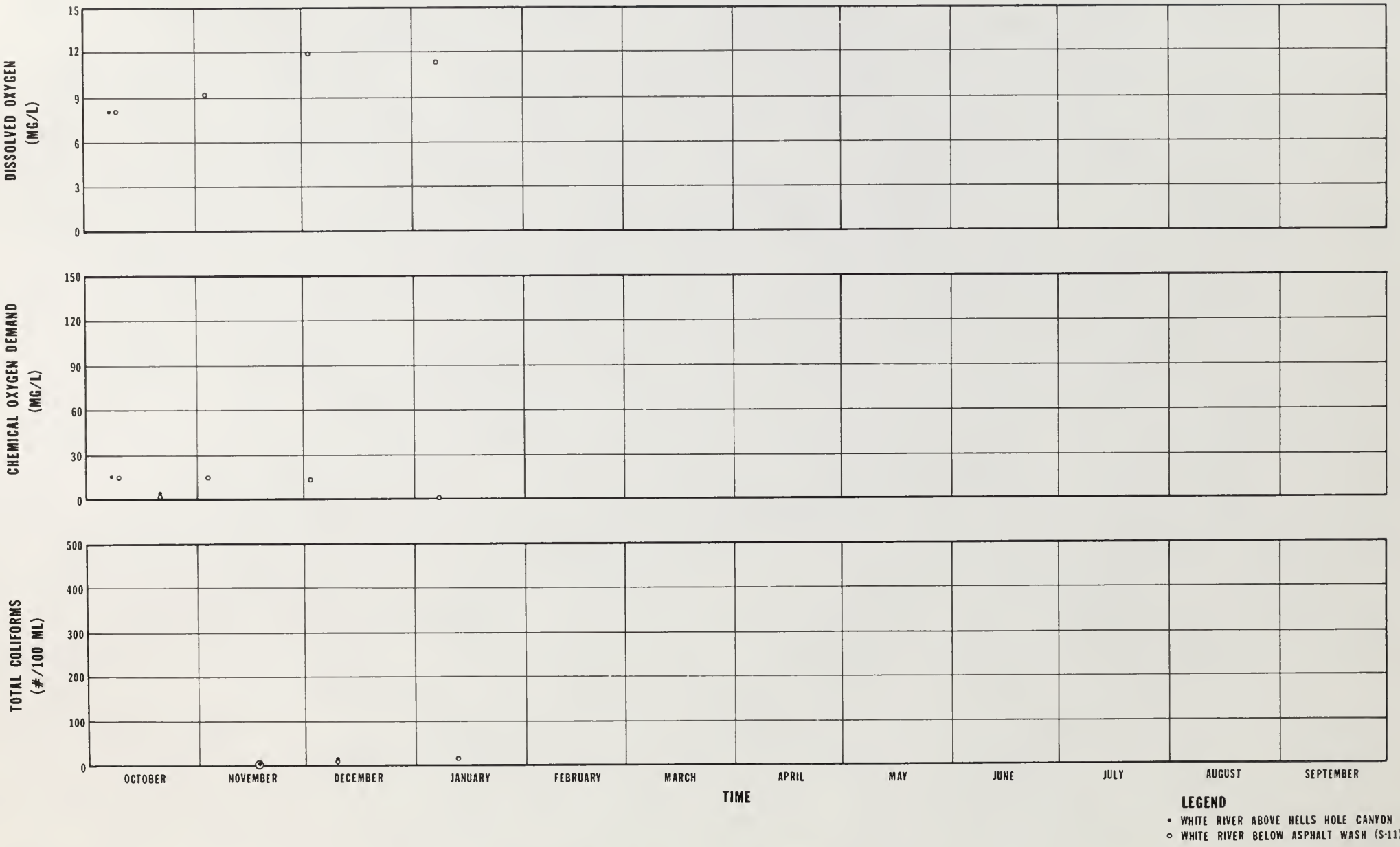
Dissolved oxygen levels in the White River have shown no unusual trends (figures II-28 and II-29), except for an unexpectedly low value, probably anomalous), in May at Station S-11. Stream dissolved-oxygen levels are usually near saturation in streams like the White River, where there are few domestic waste sources to contribute oxidizable material. Dissolved oxygen concentrations are not affected by flow directly but will change as a result of elevation or water temperature changes that alter the saturation level, or the concentrations may change as a result of production or use by aquatic organisms. Since the station elevations are fixed, the trends shown in the figures are the result of water temperature variations, with saturation levels decreasing as temperature increases. Although dissolved oxygen concentration seem to decrease across the project area, this is not likely to be an established trend.



VARIATION IN TIME OF BIOCHEMICAL CONSTITUENTS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-28



VARIATION IN TIME OF BIOCHEMICAL CONSTITUENTS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)

OCTOBER 1975 - SEPTEMBER 1976

FIGURE 11-29

Chlorophyl A concentrations are a measure of the photosynthetic life forms (such as algae) that inhabit the water. Its levels follow those of nitrate (figures II-26 and II-27) for reasons explained in the nutrient section.

Chemical oxygen demand concentrations are consistently low throughout the year except for increased levels during high flow. These increases are probably caused by oxidizable organic matter that is washed into the stream by surface runoff. None of the values are high, considering that 5 mg/l is the lower limit of accuracy for the test.

Coliforms are indicators of the presence of pathogenic organisms that enter the water through domestic wastes. Besides tests for total coliforms (shown in figures II-28 and II-29), tests have also been conducted for fecal coliforms and fecal streptococcus in the White River. The results of all three tests have indicated the same general trends of higher concentrations when conditions are suitable for the growth of aquatic organisms. Considering the low concentrations and their correlation with chlorophyl A concentrations, it appears that coliforms are unexpectedly regrowing in the White River, although they do not normally show significant growth at temperatures below 30°C. Utah water-quality standards require that total coliform levels not exceed 5000/100 ml or that fecal coliforms not exceed 2000/100 ml as monthly averages in the White River. Neither criteria was exceeded during the first year.

Trace Elements: In this report, "trace elements" is a broad category inclusive of elements rare in nature and/or only slightly soluble in the conditions in the White River. Even though these elements are present in low concentrations, they are important because their effects, either harmful or beneficial, are evident at low concentrations.

Trace elements include metals (copper, iron, molybdenum, etc.) and non metals (arsenic, selenium, phenols, etc.), but are most commonly thought of in terms of heavy metals. Figures II-30 and II-31 list three heavy metals present in measurable quantities in the White River and their variations in concentrations throughout the study area. The concentrations in the other graphs of this section, except those for pH and total coliforms, are given in mg/l, whereas the concentrations of zinc, iron, and copper are given in µg/l, a factor of 1000 smaller in scale.

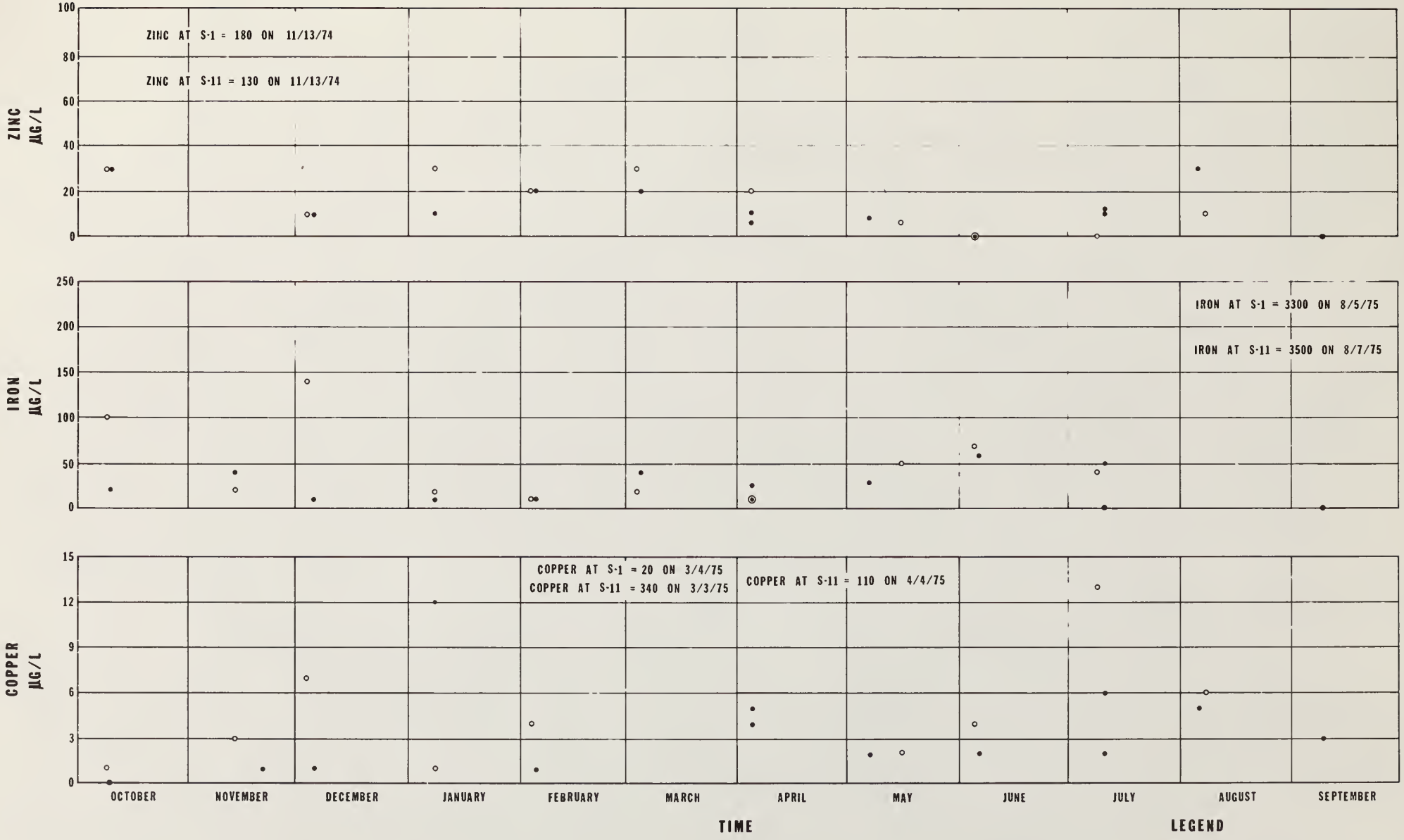
Zinc concentrations have consistently decreased slightly from baseflow to highflow whereas iron concentrations have consistently increased slightly. The variations in copper concentrations cannot be directly attributable to flow fluctuations,

even though the higher values seem to be associated with periods of runoff from the lower White River basin. There may be two explanations for the consistency in the zinc and iron samples. First, because their levels in surface runoff or ground water are similar, their concentrations in the stream are consistent. Second, whether or not their levels are similar at their sources, controls within the river maintain their concentrations. The actual mechanism is probably a combination of the two effects.

In the first 12 sample pairs, copper concentrations increased throughout the study area. A comparison of the samples from all four stations on the White River shows that copper concentration increased considerably at stations S-3 and S-4 in December, March, April, and July and perhaps in February and June, although not as much. These periods could relate to increased ground water discharge, except that copper concentrations in the samples from the bird's nest aquifer have not been high enough to cause these increases. Consequently, the increases must be the result of interflow in the soil reaching the river or some other source.

All trace elements except arsenic, boron, copper, molybdenum, strontium, vanadium, selenium, and silver have been below detection limits in at least one sample from all of the four White River stations. Even arsenic, boron, copper, molybdenum, vanadium, and silver were below detection limits at least once at each of the stations. In effect this means that only very low levels of trace elements are present in the White River. This is further confirmed by the fact that only phenols violated any water quality criteria. It is recommended that phenols not exceed 0.001 mg/l in drinking water unless no better source is available (USPHS 1969). This limit does not reflect a toxic threshold, but rather a level at which there may be an unpleasant taste to the water. Concentrations averaged 0.004 mg/l and never exceeded 0.014 mg/l. None of the pesticides that can be analyzed through gas chromatography were found in the White River.

Suspended Sediment: Suspended sediment is a major portion of the material carried by the White River. While the White River carried about 280,000 metric tons (305,000 tons) of dissolved matter during the 1975 water year, it carried about 1,200,000 metric tons (1,300,000 tons) of suspended sediment. As shown on Figure II-32, suspended-sediment concentrations are highly variable, although they do generally increase with increasing flow. The sediment concentrations are much higher in runoff from the lower basin, with its sparse vegetation, than in runoff from the forests of the upper basin; ground water seepage contains effectively no



VARIATION IN TIME OF SOME TRACE ELEMENTS

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1) AND WHITE RIVER BELOW ASPHALT WASH (S-11)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-30

suspended sediment. Besides the peaks in May and June, all other high suspended-sediment concentrations are associated with either snowmelt or rainfall runoff from the lower basin.

As shown on Figure II-20, increases in suspended sediment in the White River are noticeable between the upper and lower stations during most of June and portions of March, May, July, and August. Otherwise the concentrations are similarly low at both stations. The increases are probably caused by channel scouring during May and July and by surface runoff from the project area during the other periods. It is difficult to estimate the volume of suspended sediment carried from the tracts to the White River because runoff occurs infrequently; but when it does, it contributes a large volume of suspended sediment to the river.

In any one day, differences between any two of the four stations ranged from an increase of somewhat more than 4000 mg/l to a decrease of 2000 mg/l across the study area. These differences reflect not only suspended sediment addition or deposition within the project area but also concentration variations in time of the White River as it enters the study area, since samples were not necessarily collected from the same slug of water in each day.

Streambed samples collected at the four stations were analyzed for minerals. It can be seen in the results (Table II-6) that quartz, the crystalline form of silica, constituted the majority of the sedimentary minerals. All of the other compounds also contained silicon and oxygen as well as calcium, magnesium, aluminum, iron, and manganese in approximately that order. The suspended sediment probably has a similar composition.

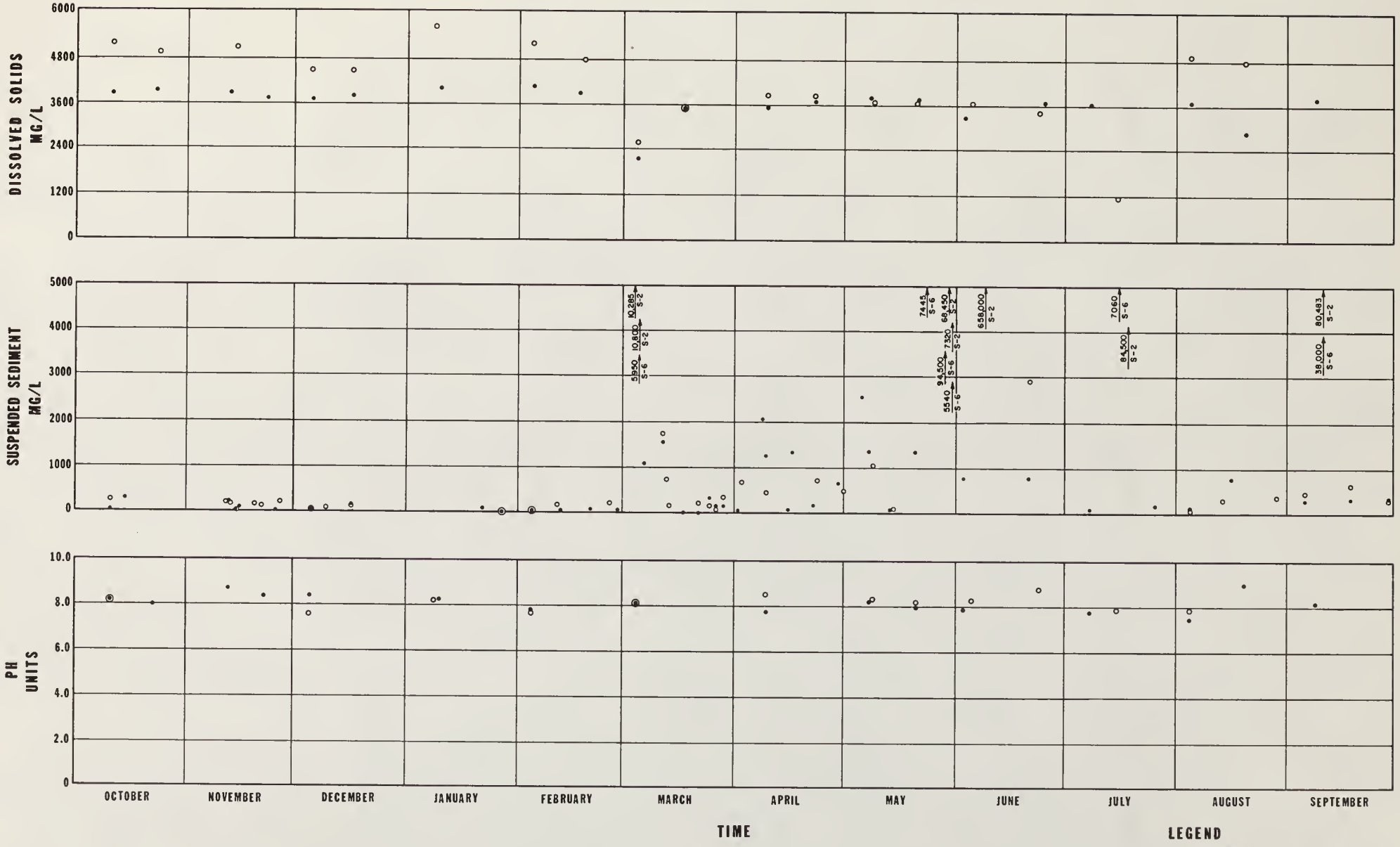
First-Year Water Quality: Evacuation Creek

Within the project area, Evacuation Creek is a much more complicated system than the White River in terms of streamflow volume and water quality. Streamflow volume is very low for most of the year and at times alternates between dry and wet parches along its length. Dissolved solids concentrations in Evacuation Creek during baseflow are about eight times higher than baseflow concentrations in the White River. During the baseflow period, samples taken at Station S-6, at the upper boundary of the project area, are about 1000 mg/l higher in dissolved solids than samples collected downstream at Station S-2 (figures II-33 and II-34). This is not the result of dilution, since streamflow at Station S-2 is equal to, or even less than, that at Station S-6, but rather because the stream is influenced by the bird's nest aquifer between these points. This is discussed in the hydrology section.

TABLE II-6

SUMMARY OF STREAMBED MINERALOGY
AT THE WHITE RIVER GAUGE SITES

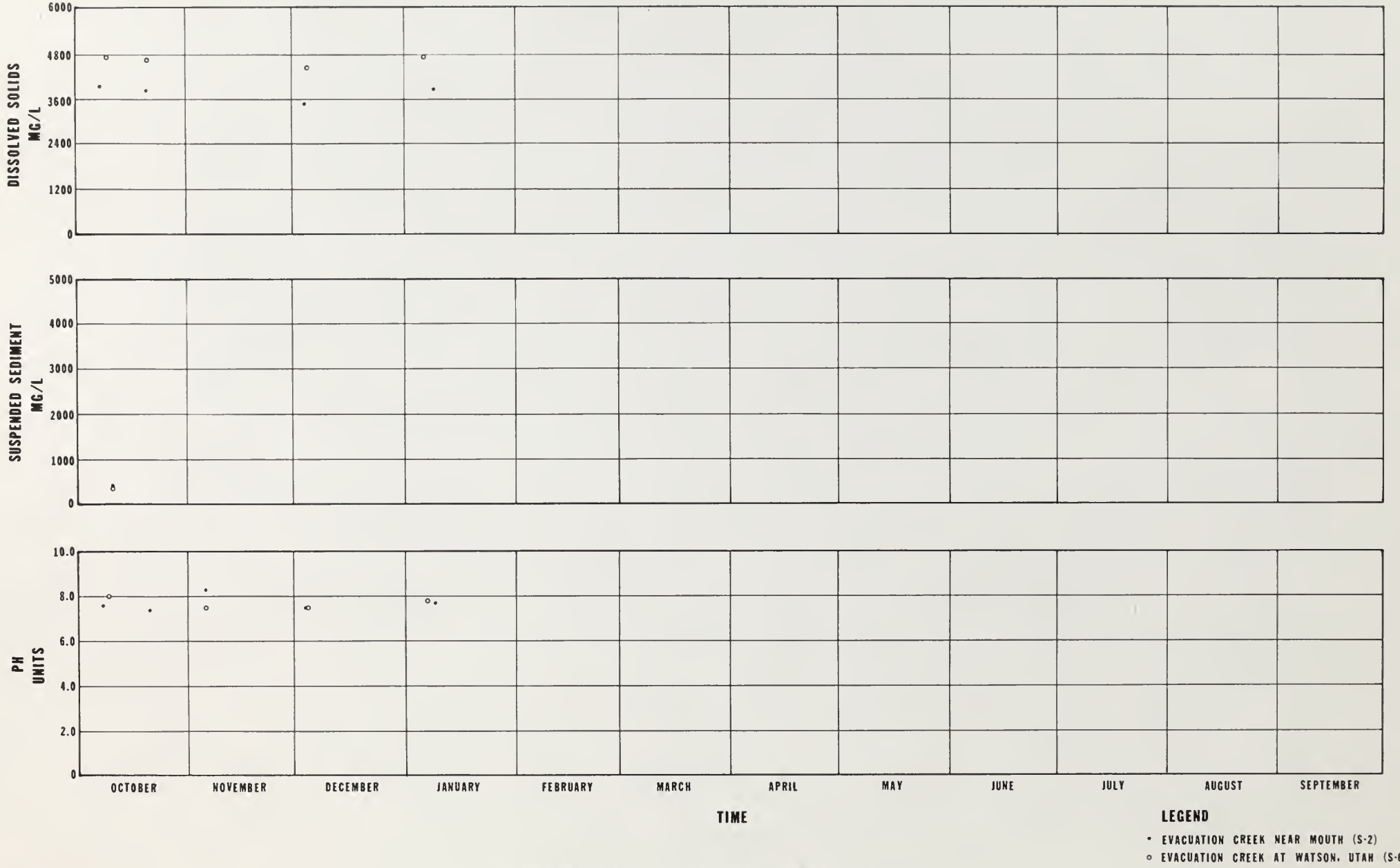
Mineral	Percent Composition			
	Mean	Standard Deviation	Maximum	Minimum
Quartz	51	8	61	38
Potassium Feldspar	8	1	9	6
Plagioclase Feldspar	7	1	8	6
Calcite	9	2	14	6
Dolomite	8	2	12	5
Clay Minerals	14	3	20	10
Analcime	1	0	2	1



VARIATION OF GENERAL CHARACTERISTICS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-33



VARIATION OF GENERAL CHARACTERISTICS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-34

Despite the different levels of dissolved solids, the other water quality parameters at stations S-2 and S-6 are similar. The dissolved solids levels very clearly indicate the change from baseflow to highflow, which lasts from March through August. During the highflow period, there is sufficient water in the stream to maintain flow between the stations, and therefore dissolved solids concentrations are similar at both sites. In August, baseflow dissolved solids conditions resume and dissolved solids concentrations at Station S-6 are greater than those at Station S-2.

Suspended-sediment concentrations are different between the baseflow and highflow period (Figure II-33). During baseflow, concentrations are very low, as expected for ground water seepage. During highflow, suspended-sediment concentrations vary considerably in response to streamflow variations, which occur over very short time intervals, as shown on Table II-7. The suspended-sediment concentrations were measured during a period of snowmelt, when streamflow volumes were relatively high during the day because of solar radiation promoting melting, but were very low at night, when subfreezing air temperatures inhibited melting. Similar variations occurred during thunderstorms as the result of brief but intense rainfall (e.g., the high values given on Figure II-33 for May through September).

Streambed samples collected at the Evacuation Creek gauging sites were very different from similar samples from the White River (Table II-8). The percentage of quartz was much lower in the Evacuation Creek samples, but calcite and dolomite were higher. Both calcite and colomite can be formed by evaporation, so their presence may relate to seepage from the bird's nest aquifer. Streambed samples from the two dry wash stations in Evacuation Creek indicate that clay minerals are dominant (30 percent), with calcite almost as high (19 percent), and that quartz, plagioclase feldspar, and dolomite are similar (17 percent). Clay minerals are probably in higher concentrations because they are a higher fraction of the soils in these drainages than in the overall Evacuation Creek drainage.

The pH of Evacuation Creek is very similar to that of the White River (figures II-33 and II-34). It is slightly alkaline and shows little variation throughout the year, indicating that the ground water seepage rapidly equalized with surface conditions.

TABLE II-7

SUSPENDED SEDIMENT CONCENTRATIONS
OBSERVED AT STATION S-2
March 3-4, 1975

Time	Streamflow m^3/s (cfs)	Suspended Sediment Concentration mg/l
3-3 12:45	0.35 (12.2)	10,285
3-4 13:24	0.02 (0.7)	1,210
3-4 16:10	0.31 (11.0)	10,800
3-4 17:00	0.29 (10.3)	6,865

TABLE II-8

SUMMARY OF THE MINERALOGY
OF THE STREAMBED AT THE EVACUATION
CREEK GAUGING SITES
(7 samples)

	Percent Composition			
Mineral	Mean	Standard Deviation	Maximum	Minimum
Quartz	33	8	44	21
Potassium Feldspar	6	1	8	4
Plagioclase Feldspar	7	2	8	4
Calcite	14	3	18	11
Dolomite	17	5	27	12
Clay Minerals	14	2	15	10
Analcime	2	1	3	1
	93			

Major Dissolved Elements - Cations: As seen in figures II-35 and II-36, throughout the year the concentrations of sodium are at least three times higher than those of either calcium or magnesium. Concentrations of calcium, magnesium, and sodium have paralleled those of total dissolved solids, except that sodium concentrations were slightly lower in the first June samples. The widest variations in quality between the two stations were found in the July samples as a result of a rapid change in streamflow, apparently from rainfall in the upper Evacuation Creek basin. From the previous hydrographs it can be seen that Station S-2 was sampled at a time of falling stage (and increasing specific conductance) and that Station S-6 was sampled at a time of rising stage (and rapidly decreasing specific conductance), so that although the samples were collected within a day of each other, they measure entirely different events.

Sodium concentrations are high enough that the water should be used for irrigation only as a supplement for other sources. The SAR varied from a high of 12 at Station S-6 during baseflow to a low of 5.4 at Station S-6 during highflow. (The values at Station S-2 were somewhere between the percentage of sodium in the samples varying from 63 percent at Station S-6 during baseflow to 57 percent at Station S-2 during highflow.) The water in Evacuation Creek was always extremely hard. The hardness concentrations ranged from a high of 1600 mg/l to a low of 340 mg/l, both at Station S-6.

Major Dissolved Elements - Anions: The major anoins generally follow the same trends as the total dissolved solids and cations, diverging only occasionally (figures II-37 and II-38). Bicarbonate levels were much lower in early June, and dissolved solids concentrations remained steady. The decrease coincides with decreased sodium concentrations. The differences may be because these samples were collected as water levels receded from a very high flow following rains at the end of May. In fact, there does not appear to be any other explanation, since neither the pH nor any of the other constituent concentrations were unusual. The changes may be important because sodium and bicarbonate combined as a mineral would be nahcolite, the mineral assumed to have leached from the aquifer, leaving cavities that look like bird nests. (Alkalinity concentrations were between 470 mg/l and 120 mg/l.)

Sulfate is clearly the dominant anion at both stations. This further supports the contention that ground water seepage is the principal source of flow in Evacuation Creek. Sulfate concentrations were never less than 800 mg/l and sometimes exceeded 3000 mg/l which were normally far above the 250 mg/l recommended maximum concentration for drinking water (USPHS 1969), established because of the laxative effect of waters containing concentrations higher than this.

Chloride and fluoride were both found in much lower concentrations. Chloride ranged from 18 mg/l to 87 mg/l and fluoride from 1.5 mg/l to 1.1 mg/l.

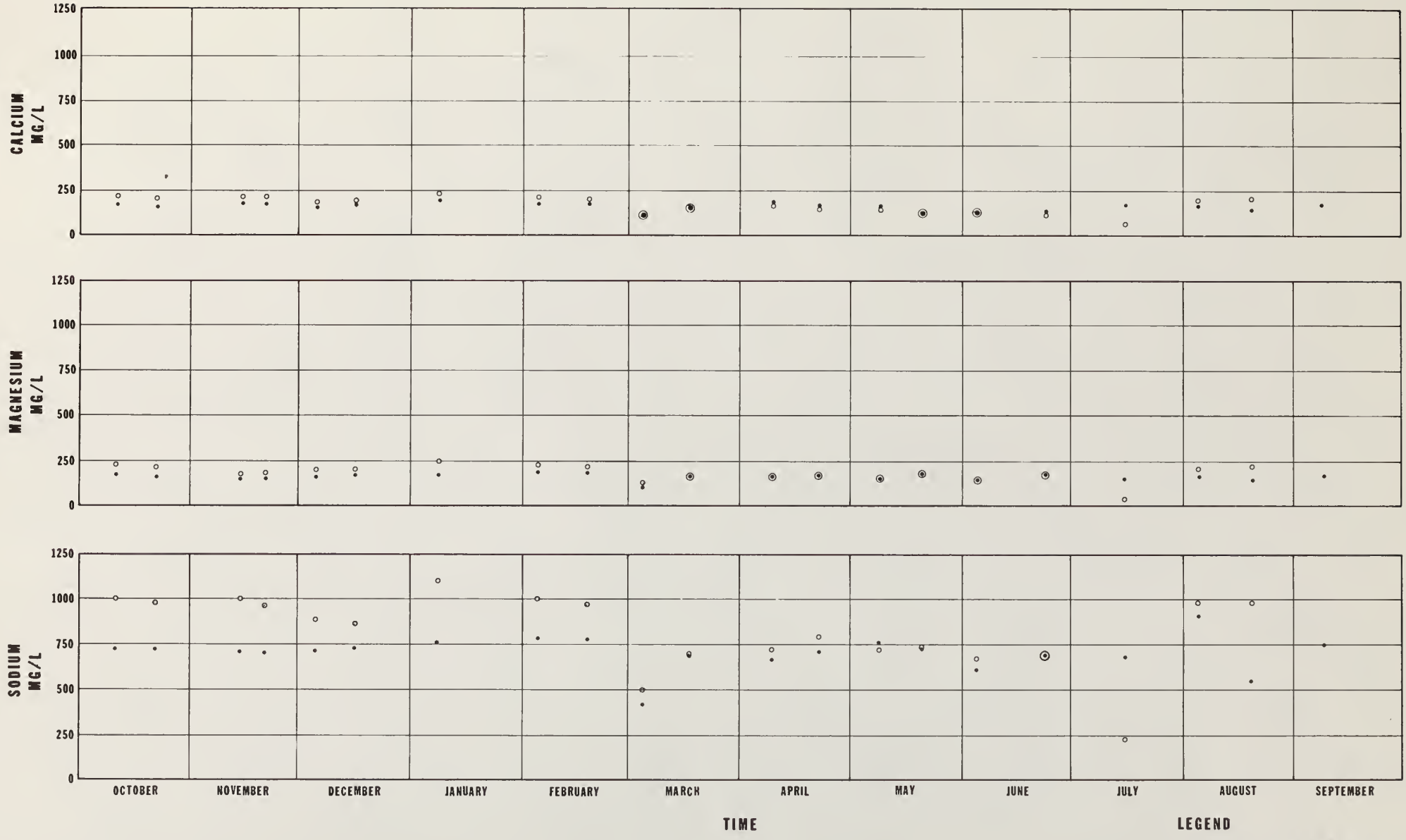
Nutrients: The nutrient concentrations in Evacuation Creek (figures II-39 and II-40) differ from those found in the White River. Although phosphorus concentrations are somewhat lower than those in the White River during baseflow and are somewhat higher during highflow, phosphorus concentrations generally follow the same trends.

Ammonia and nitrate concentrations, on the other hand, do not follow the trends found in the White River. Nitrate concentrations are highest during highflow and reach maximum that are four times higher than the maximum found in the White River. The peak concentrations occur in April and decrease thereafter. Concentrations occur in April and decrease thereafter. Concentrations during baseflow are below those found in the White River. It is apparent from these trends that nitrate is virtually absent in the ground water seepage that sustains the baseflow but is found in very high concentrations in the surface runoff. There are no apparent variations that relate to biological use of nitrate.

Ammonia concentrations are generally similar to those found in the White River but vary more widely, particularly during winter 1974. These variations do not seem to relate to changes in streamflow, water source, or gauging station. They cannot be explained at this time, and these trends are not being repeated in data collected during 1975 (Figure II-40). Ammonia concentrations did not exceed the toxic threshold of 1.0 mg/l during baseflow or 0.27 mg/l (NAS 1972; EIFAC 1970) during highflow at any time. Total kjeldahl nitrogen concentrations seemed to directly follow the surface runoff pattern and varies from .44 mg/l to 5.0 mg/l at Station S-2.

Silica concentrations averaged between 8 mg/l and 10 mg/l without showing any strong seasonal trends. The TOC and TIC levels varied widely, with no seasonal trends. The TOC was a maximum of 3 mg/l at Station S-6 and was a minimum of 8.1 mg/l at Station S-2, both during highflow. The TIC was a maximum of 90 mg/l at Station S-6 during baseflow. No samples for the TIC were taken at either station during highflow.

Biochemical Constituents: Dissolved oxygen levels in Evacuation Creek have been very close to saturation throughout the study period (figures II-41 and II-42). Dissolved oxygen values were lower at Station S-6 than at Station S-2 during winter, which may indicate that ice cover limited reaeration above Station S-6 but not above Station S-2. During summer,

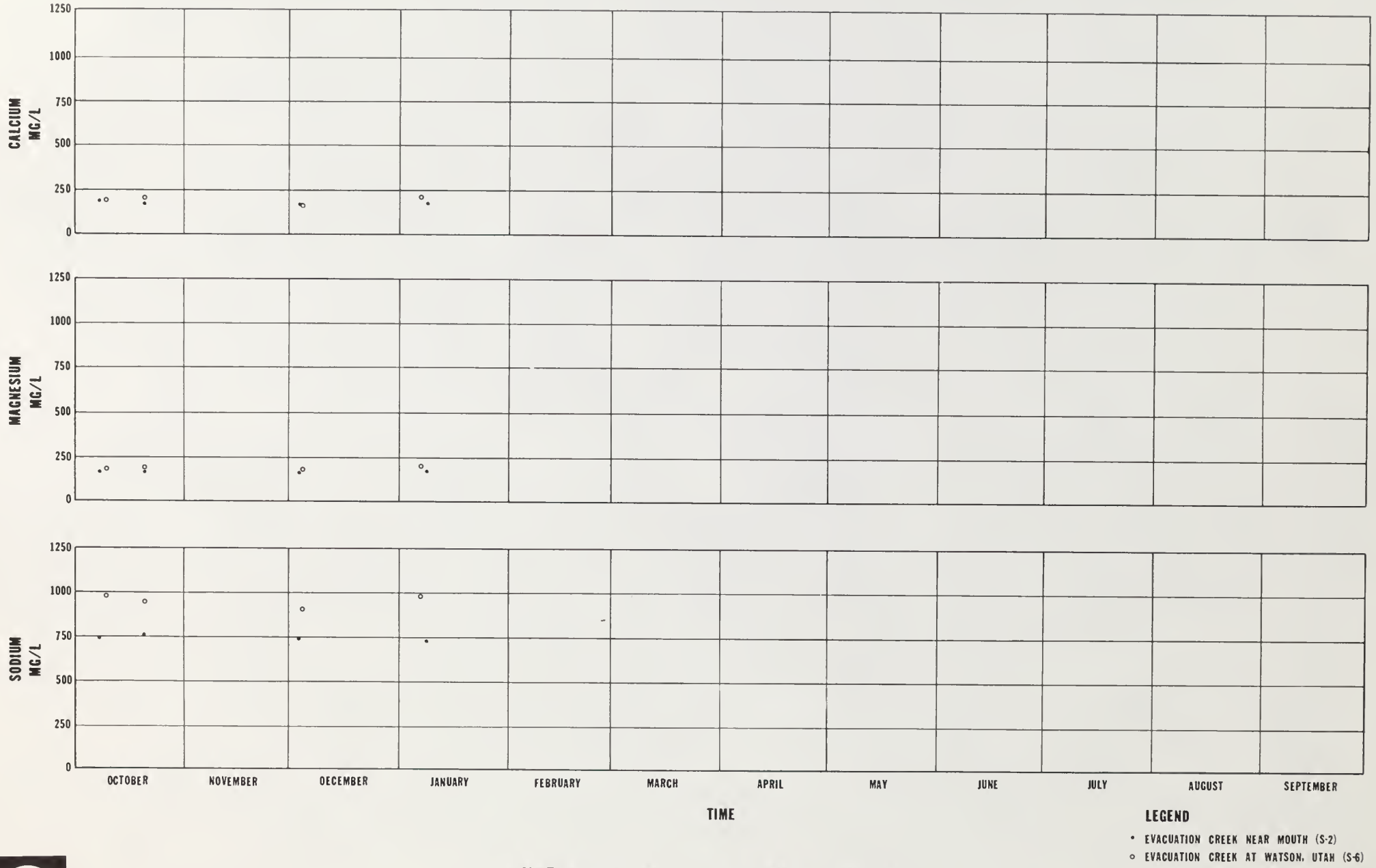


VARIATION IN TIME OF MAJOR CATIONS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)

OCTOBER 1974 - SEPTEMBER 1975

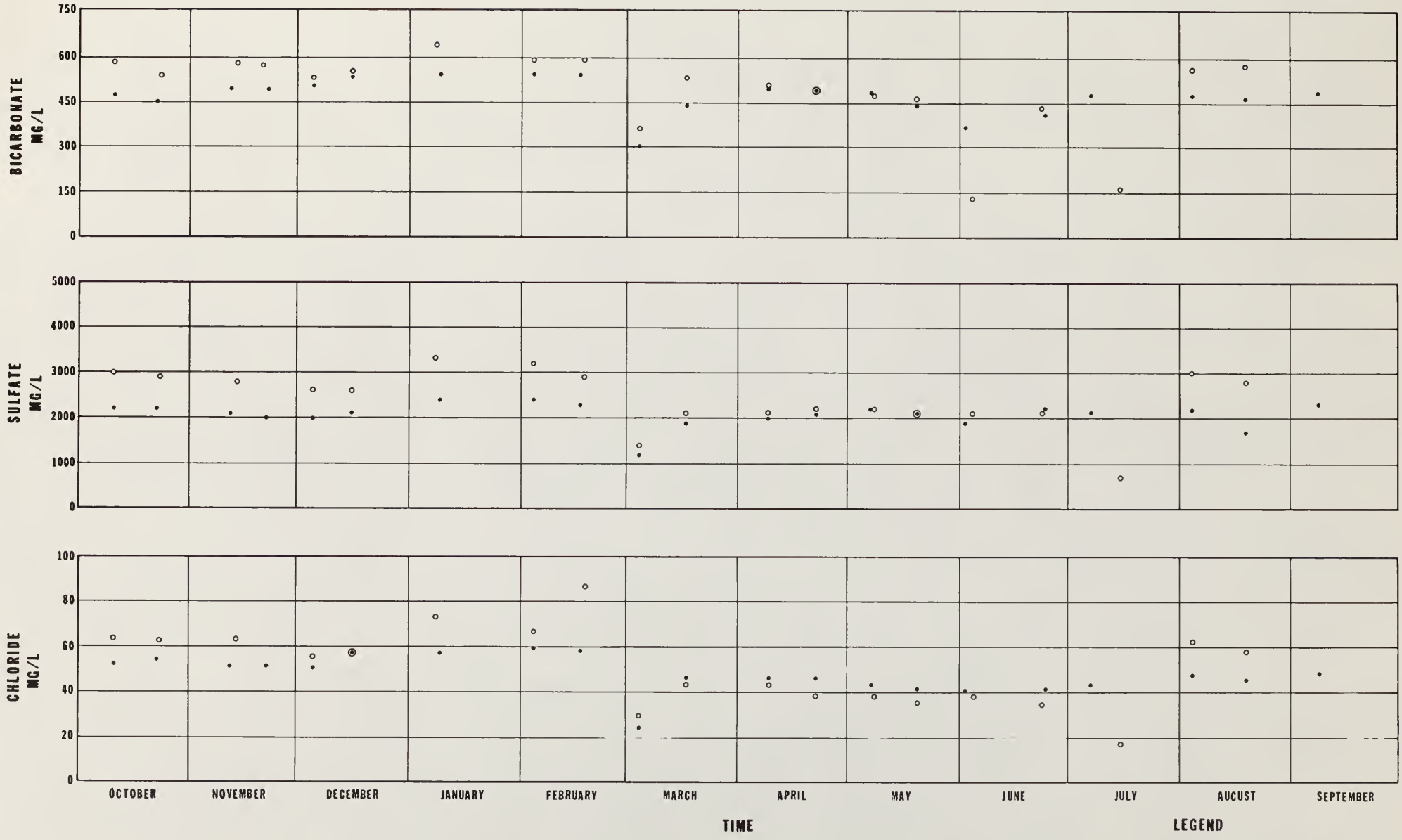
FIGURE II-35



VARIATION IN TIME OF MAJOR CATIONS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-36

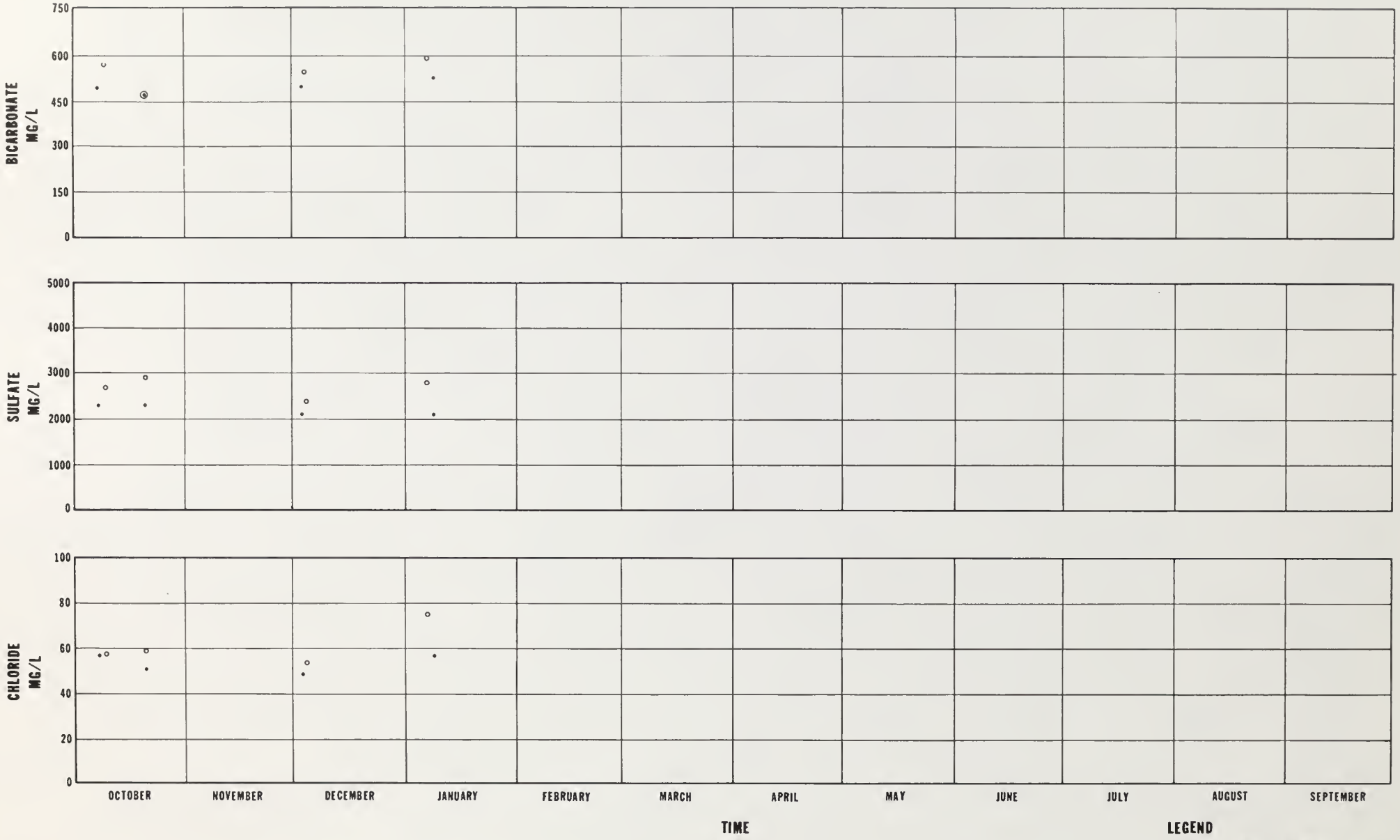


VARIATION IN TIME OF MAJOR ANIONS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)

OCTOBER 1974 - SEPTEMBER 1975

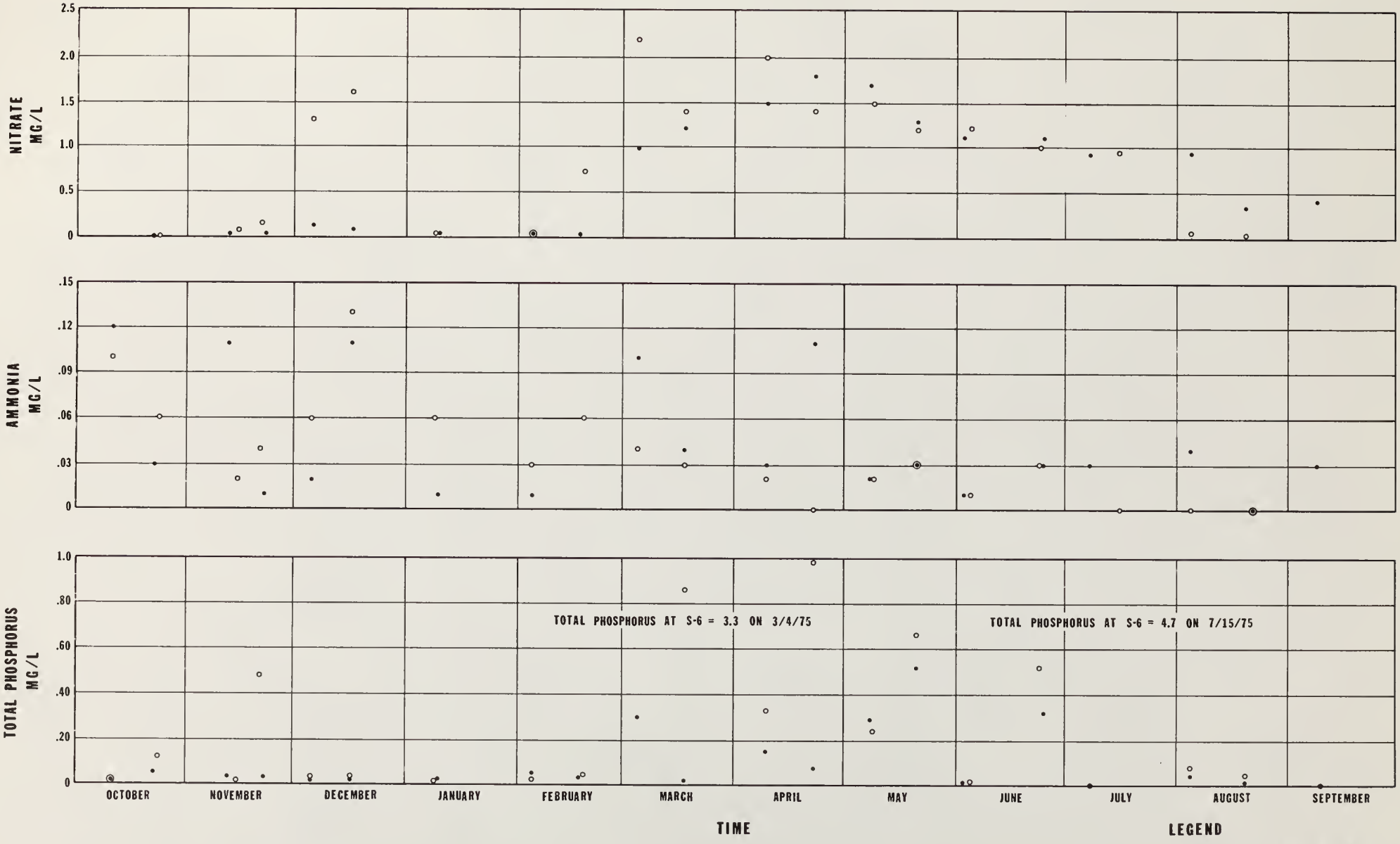
FIGURE II-37



VARIATION IN TIME OF MAJOR ANIONS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1975 - SEPTEMBER 1976

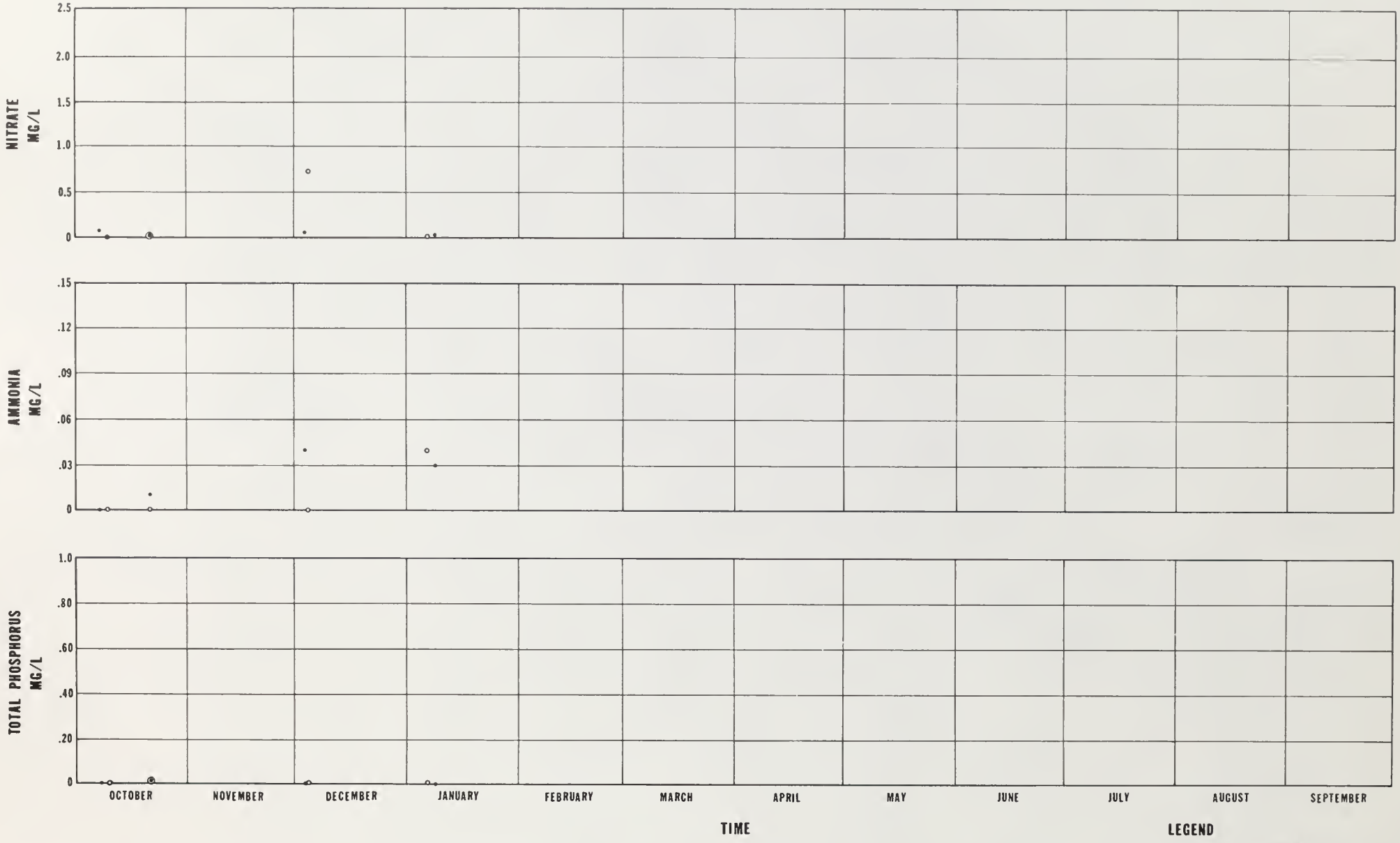
FIGURE II-38



VARIATION IN TIME OF REPRESENTATIVE NUTRIENTS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1974 - SEPTEMBER 1975

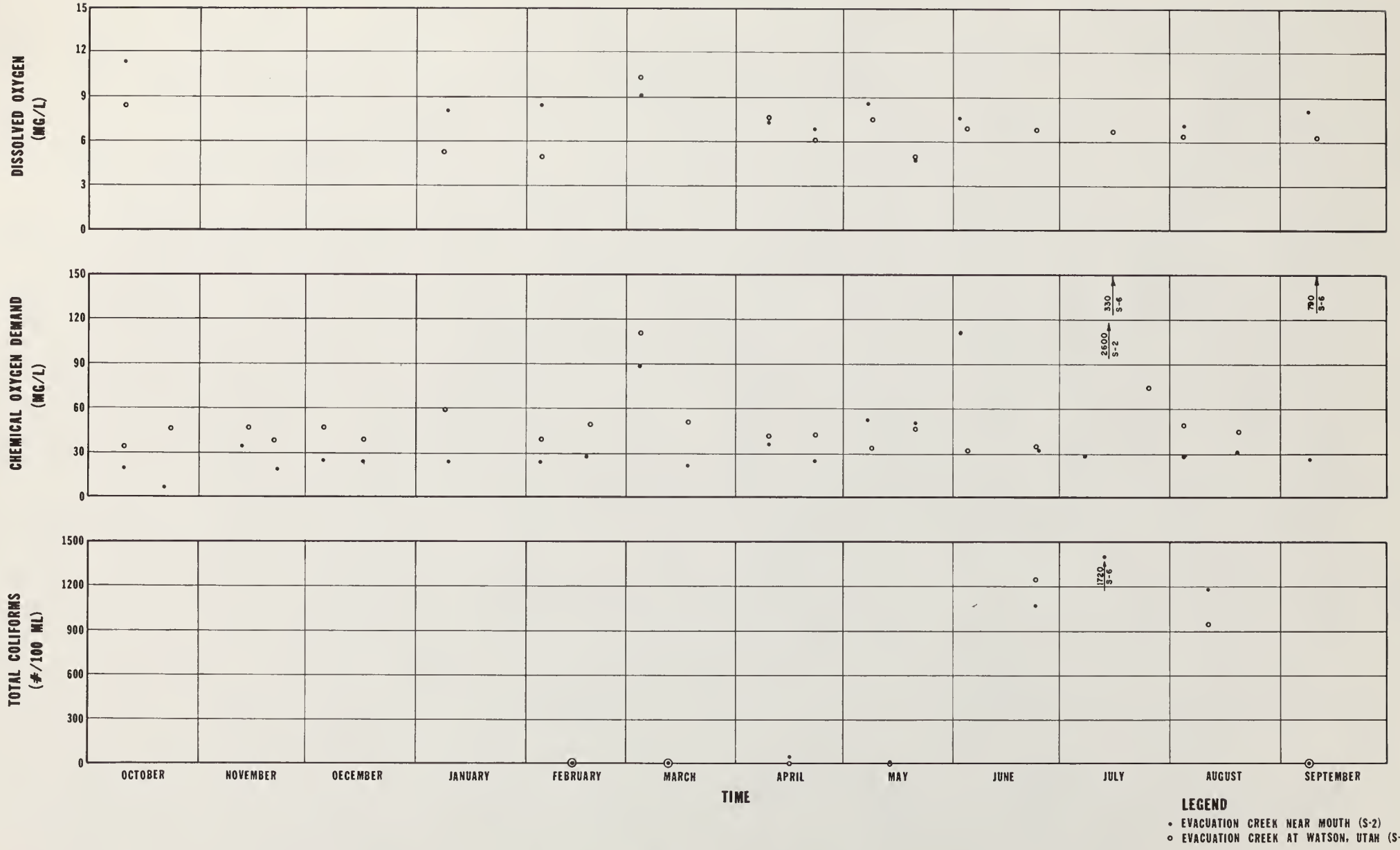
FIGURE II-39



VARIATION IN TIME OF REPRESENTATIVE NUTRIENTS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-40

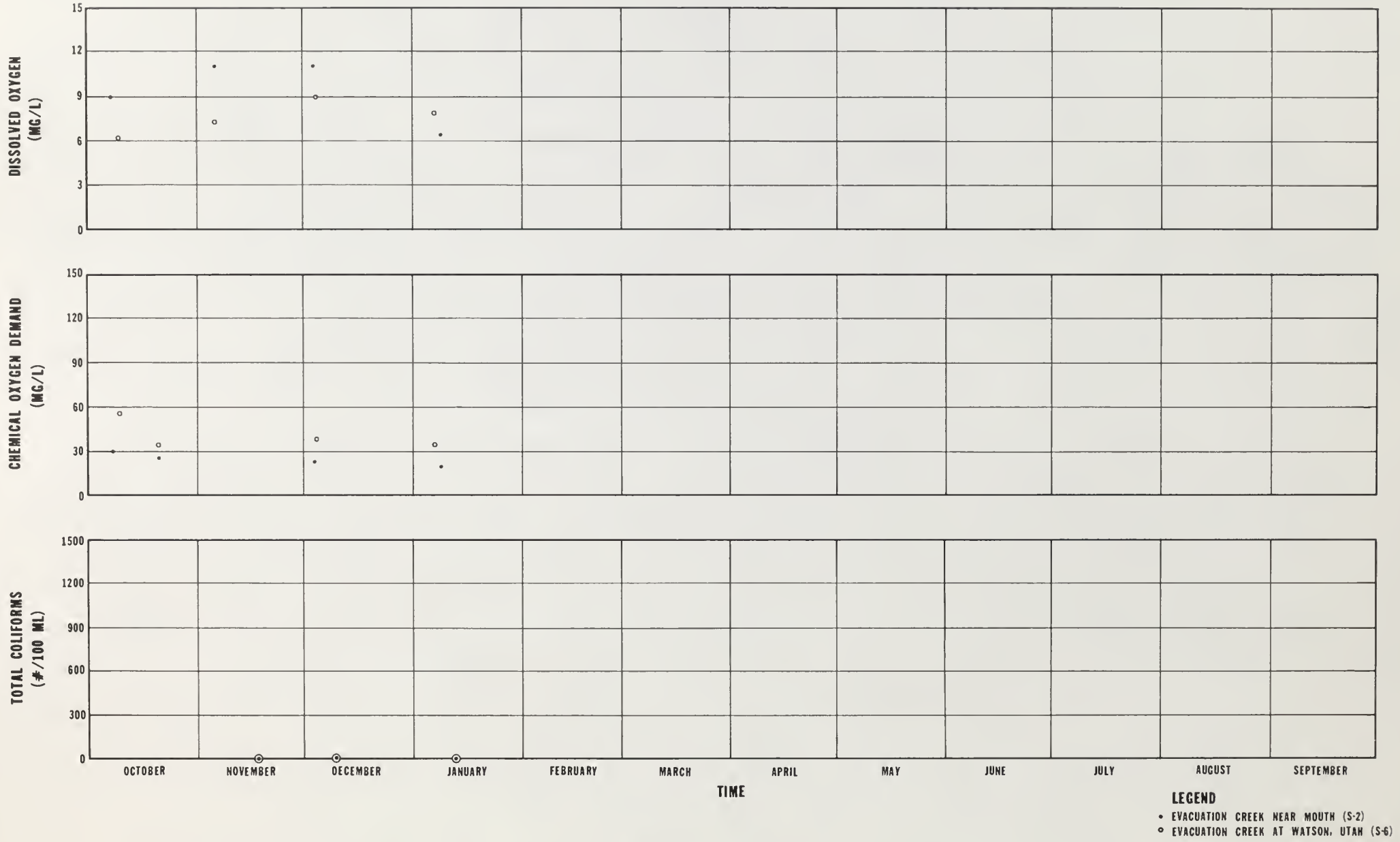


VARIATION IN TIME OF BIOCHEMICAL CONSTITUENTS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)

OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-41



VARIATION IN TIME OF BIOCHEMICAL CONSTITUENTS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)

OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-42

dissolved oxygen concentrations are similar at both stations, indicating that surface runoff, which contributes to streamflow during this period, is effectively saturated through exposure to the atmosphere. Chlorophyll A concentrations in Evacuation Creek have been somewhat higher than those in the White River. Concentrations at Station S-6 at Watson ranged from .0 mg/l to 19 mg/l and have corresponded to either the seasonal flow cycle, nutrient increases, or temperature cycle. It is possible that one or more of the trace elements is acting to limit algal growth.

Chemical oxygen demand concentrations are low at both stations throughout the year, except in samples taken during high surface runoff (figures II-41 and II-42). This is as expected, since surface runofff will carry oxidizable organic matter, while ground water usually does not. The upstream station samples (S-6) appear generally to have slightly higher concentrations than samples taken at Station S-2. There is no explanation for this at this time.

Coliforms were found in appreciable quantities in Evacuation Creek only during June, July, and August. This was unexpected, since these months do not relate to either the winter sheep grazing from about October until April or to the highflow period from March through July. No total coliform count exceeded the 5000/100 ml maximum, but the July fecal coliform count of 6620/100 ml did violate the 2000/100 ml criteria. This one sample may have been either erroneous or not representative.

Trace Elements: Concentrations of trace elements in Evacuation Creek are somewhat similar to those of the White River in terms of the number and type of elements present, but the concentrations of these elements vary considerably. As in the White River, beryllium, bismuth, gallium, geranium and zirconium were at least below detection limits in all samples. Silver was above detection limits only once, at 0.001 m/l at Station S-6, and tin exceeded detection limits at Station S-7 only once, at 0.06 mg/l. Unlike the White River, titanium also fell below detection limits in all samples in Evacuation Creek, and barium exceeded detection limits only twice, 0.1 mg/l at Station S-2 and 0.4 mg/l at Station S-7. Cadmium was also effectively absent, with only one sample of 0.001 mg/l detectable at Station S-2. Of the other elements, only copper, iron, boron, strontium, and lithium were always detectable, with the remainder showing seasonal absence or concentrations that were continually near detection limits.

Figures II-43 and II-44 give copper, iron, and zinc concentrations for the upstream and downstream stations on Evacuation Creek during the first year of monitoring. Iron

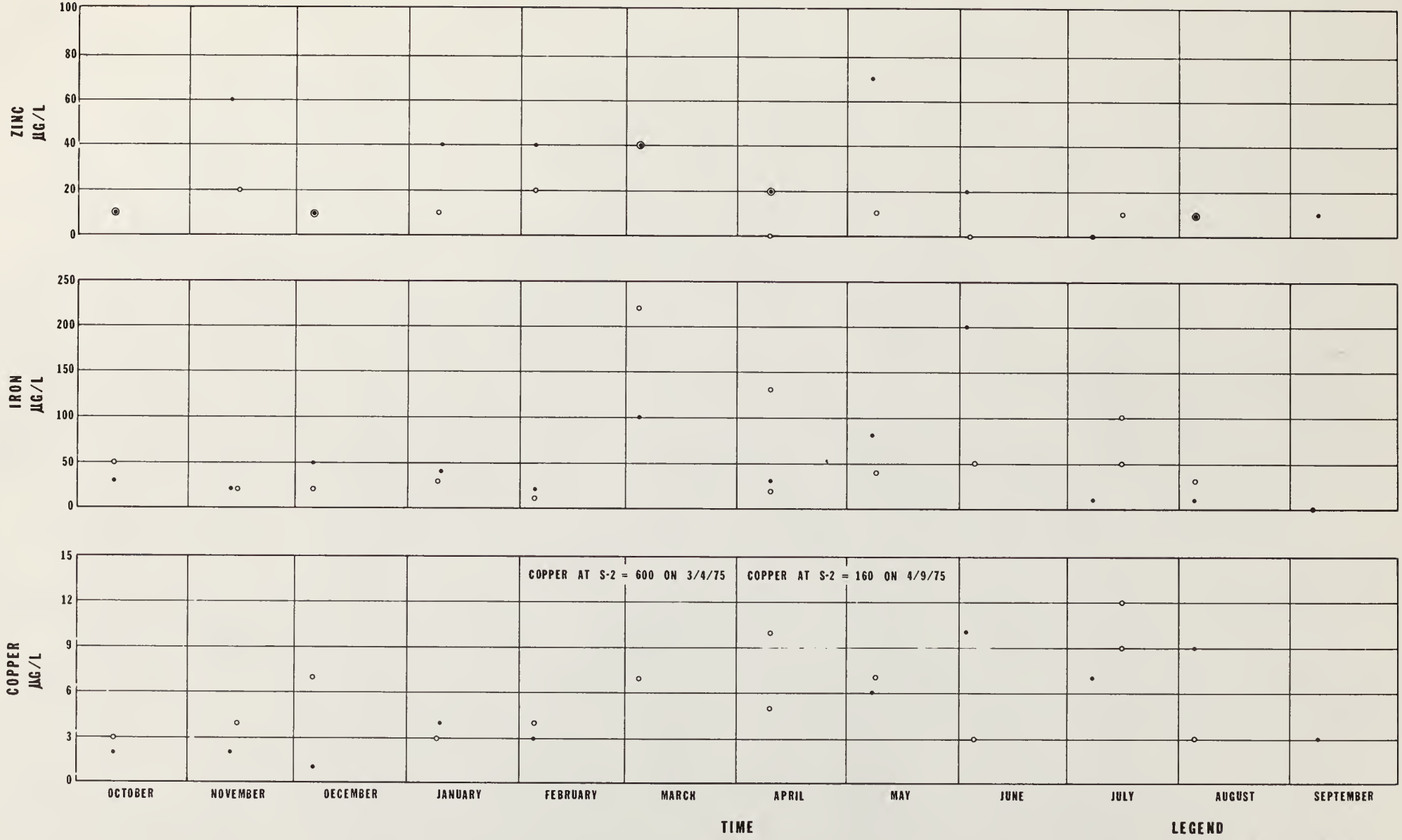
concentrations are clearly higher during highflow than during baseflow. Copper concentrations show a similar pattern, although not as distinct as those of iron. Zinc levels remain constant throughout the year. In terms of mean concentrations during each period, iron is 290 percent higher during highflow than during baseflow. Copper shows somewhat over a 70 percent increase, while zinc is effectively unchanged, with only a 7 percent increase. Boron, manganese, and strontium concentrations decreased with increased flow, following a trend opposite to that of iron.

In relation to standards, the mean concentration of molybdenum has exceeded the NAS wildlife-use criteria at all stations during highflow and baseflow. Mean boron concentrations far exceeded the NAS drinking water and irrigation criteria at stations S-7 and S-2 during baseflow and were above the criteria at stations S-6 and S-2 during highflow. During baseflow the mean concentrations of both manganese (at stations S-6 and S-2) and selenium (at S-7) exceeded the NAS and U.S. Public Health Service Drinking Water Criteria. Phenols also exceeded these criteria during both highflow and baseflow at Stations S-7, S-6 and S-2. Along with the previously noted high sulfate concentrations, the exceptions noted here are a strong indication that water from Evacuation Creek should be used with caution. None of the pesticides that can be measured by gas chromatography were found in Evacuation Creek.

First-Year Water Quality: The Dry Washes--Southam Canyon, Hells Hole Canyon, and Asphalt Wash

The results of water-quality samples from Hells Hole Canyon and Asphalt Wash are shown in Table II-9. Unfortunately, no samples could be collected from Southam Canyon. The quality of the water in Hells Hole Canyon water is similar to that of Evacuation Creek water; that is, the dissolved elements are dominated by calcium, sodium, and sulfate. Samples from Asphalt Wash indicate water at a better quality, with dissolved solids of calcium, sodium, and bicarbonate predominant. Samples of Asphalt Wash water indicate that the dissolved-solids level is less than 60 percent of the dissolved-solids level of Hells Hole Canyon water. It is possible that the differences in quality reflect differences in the time the samples were taken rather than actual differences in overall quality.

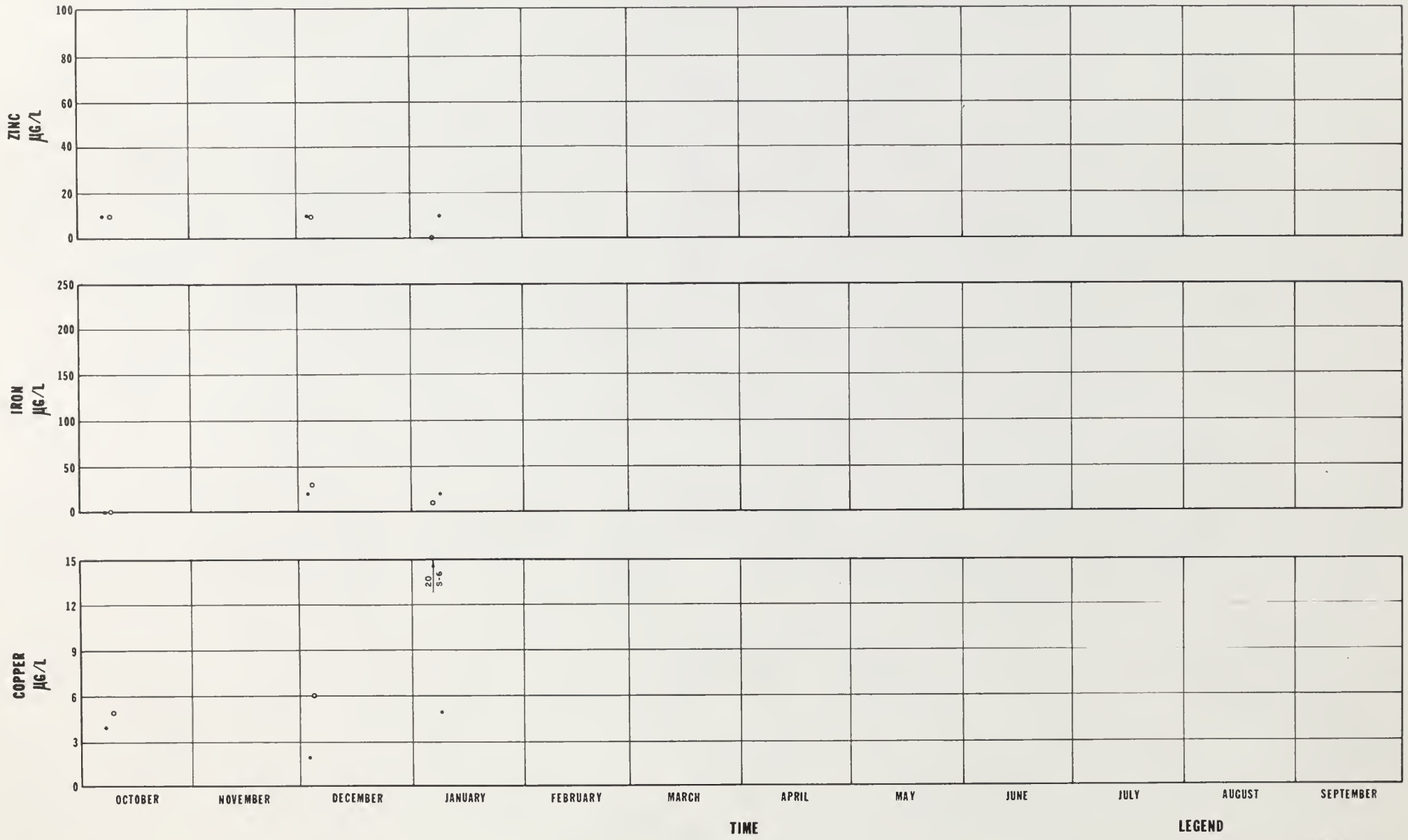
In the July 16, 1975 sample from Hells Hole Canyon, iron and manganese concentrations were above standards (USPHS)1969), and in the August 14, 1975 sample from Asphalt Wash. Similarly, arsenic violated drinking water standards (USPHS)1969).



VARIATION IN TIME OF SOME TRACE ELEMENTS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1974 - SEPTEMBER 1975

FIGURE II-43



VARIATION IN TIME OF SOME TRACE ELEMENTS

EVACUATION CREEK NEAR MOUTH (S-2) AND EVACUATION CREEK AT WATSON, UTAH (S-6)
OCTOBER 1975 - SEPTEMBER 1976

FIGURE II-44

TABLE II-9

WATER QUALITY RESULTS FROM THE WASHES 1975

	Hell's Hole Canyon At Mouth (S-5)		Asphalt Wash At Mouth (S-12)
	July 16	Aug. 18	Aug. 14
Temperature (°C)	-	-	-
Turbidity (JTU)	-	190	2300
Conductance (umhos)	2020	-	-
Chemical Oxygen Demand (mg/l)	-	-	-
pH (pH Units)	-	-	-
Carbon Dioxide (mg/l)	-	-	-
Alkalinity (mg/l $CACO_3$)	189	93	189
Bicarbonate (mg/l HCO_3)	231	113	230
Carbonate (mg/l CO_3)	-	-	-
Filterable Residue (mg/l)	-	-	-
Oil & Grease (mg/l)	-	-	-
Ammonia (mg/l N)*	-	0.00	0.00
Nitrite (mg/l N)*	-	0.12	0.06
Nitrate (mg/l N)*	-	0.77	3.4
Kjeldahl Nitrogen (mg/l N)	-	1.5	4.4
NO_2 + NO_3 (mg/l N)*	0.04	0.89	3.5
Orthophosphate (mg/l PO_4)*	0.00	0.00	0.34
Phosphorous (mg/l)	-	0.07	5.9
Orthophosphorous (mg/l P)*	0.00	0.00	0.11
Total Organic Carbon (mg/l)	-	-	-
Total Inorganic Carbon (mg/l)	-	-	-
Cyanide (mg/l)	-	-	-
Sulfide (mg/l)*	-	0.2	0.2
Hardness (mg/l Ca, Mg)	810	290	68
Non Carbonate Hardness (mg/l)	620	200	0
Calcium (mg/l)*	260	84	19
Magnesium (mg/l)*	38	19	4.9
Sodium (mg/l)*	160	39	84
Sodium Adsorption Ratio	2.5	1.0	4.4
% Sodium	30	22	71
Potassium (mg/l)*	11	7	5.5
Chloride (mg/l)*	9.0	4.1	12
Sulfate (mg/l)*	950	260	34
Fluoride (mg/l)*	0.4	0.4	0.5
Silica (mg/l)*	15	7.5	14
Arsenic (mg/l)*	-	0.001	0.037
Barium (mg/l)*	-	-	-
Beryllium (mg/l)*	-	-	-
Bismuth (mg/l)*	-	-	-
Boron (mg/l)*	0.210	0.090	0.280
Cadmium (mg/l)*	-	-	-
Chromium (mg/l)*	-	-	-
Cobalt (mg/l)*	-	-	-
Copper (mg/l)*	-	0.017	0.045
Iron (mg/l)*	0.420	0.070	0.240
Lead (mg/l)*	-	-	-
Manganese (mg/l)*	0.520	-	-
Mercury (mg/l)*	-	0.0000	0.0000
Molybdenum (mg/l)*	-	-	-
Nickel (mg/l)*	-	-	-
Silver (mg/l)*	-	-	-
Strontium (mg/l)*	-	0.890	0.340
Vanadium (mg/l)*	-	-	-
Zinc (mg/l)*	-	0.130	0.120
Tin (mg/l)*	-	-	-
Aluminum (mg/l)*	-	0.000	0.090
Gallium (mg/l)*	-	-	-
Germanium (mg/l)*	-	-	-
Lithium (mg/l)*	-	0.010	0.040
Selenium (mg/l)*	-	0.002	0.001
Titanium (mg/l)*	-	-	-
Zirconium (mg/l)*	-	-	-
Gross Beta (mg/l Cs_{137})*	-	-	-
Chlorophyll A (mg/l)	-	-	-
Chlorophyll B (mg/l)	-	-	-
Phenols (mg/l)	-	-	-
Dissolved Solids (mg/l)*	-	500	351
Gross Alpha (mg/l U)*	-	-	-
Gross Beta (mg/l SR_{90}/Y_{90})*	-	-	-

*Elements analyzed only for dissolved fraction

The washes then are probably not good water supplies for domestic use even when they do flow.

Tables II-10, II-11, and II-12 show the results of analysis of the streambed material for minerals. There appear to be two different types of sediment which correspond to the three different areas of soil. Sediment samples of Hells Hole Canyon correspond to sediment samples of Evacuation Creek in tnat they are low in feldspar but high in dolomite and clay. The second type of sediment is typified by that found in Southam Canyon and Asphalt Wash. These sediment samples are high in feldspar but low in dolomite.

As expected, these two distinct sediment types seem to correspond to the distribution of minerals in the soils of their respective drainages. In comparing sediment sample results from the washes to those sediment samples of the White River, only the clay minerals are similar in percentage, while all other minerals except quartz are a much higher percentage of the sediment in the washes. While quartz is about half of the streambed material in the White River it is only a quarter of the material in the washes.

Relationships Between Constituents

Several relationships among elements in the White River are worth discussing. Perhaps the most important and the most clearly defined of these is the electrical balance between the anions and the cations. Figure II-45 shows this balance for the White River and Evacuation Creek stations during the baseflow period, and Figure II-46 shows this balance for the highflow period. Since the major ions plotted in terms of electrical charge represent the majority of the dissolved ions, they should be in balance, since the water is electrically neutral. Any significant variation from this balance is an indication that one or more of the tests is suspect. Since the balance is close, however, no problems are indicated.

Such plots are also useful for characterizing water type and identifying changes in water chemistry from one location to another and from one time period to another. Evacuation Creek is clearly a sodium-sulfate type of water, while the White River does not seem to be dominated by any particular major ions; the water quality does, however, tend towards calcium-bicarbonate during highflow and calcium, sodium-bicarbonate, and sulfate during low flow. Little change is evident from one station to another on the White River during either high or low flow, but the higher dissolved solids concentration is quite evident during low flow. During the

TABLE II-10

SUMMARY OF THE MINERALOGY
OF THE STREAMBED AT THE HELLS HOLE
CANYON GAUGING SITES
(3 Samples)

	Percent Composition			
Mineral	Mean	Standard Deviation	Maximum	Minimum
Quartz	22	3	25	19
Potassium Feldspar	6	3	9	4
Plagioclase Feldspar	12	11	24	5
Calcite	13	2	14	11
Dolomite	18	8	25	9
Clay Minerals	17	3	20	15
Analcime	2	1	3	1

TABLE II-11

SUMMARY OF THE MINERALOGY
OF THE STREAMBED AT THE SOUTHAM
CANYON GAUGING SITES
(6 Samples)

Mineral	Percent Composition			
	Mean	Standard Deviation	Maximum	Minimum
Quartz	26	2	29	24
Potassium Feldspar	14	3	18	11
Plagioclase Feldspar	18	5	27	11
Calcite	9	1	10	8
Dolomite	5	1	6	4
Clay Minerals	10	4	15	5
Analcime	9	1	12	8

TABLE II-12

SUMMARY OF THE MINERALOGY
OF THE STREAMBED AT THE ASPHALT
WASH GAUGING SITES
(6 Samples)

Mineral	Percent Composition			
	Mean	Standard Deviation	Maximum	Minimum
Quartz	27	1	29	25
Potassium Feldspar	11	2	13	6
Plagioclase Feldspar	21	7	28	9
Calcite	12	2	15	10
Dolomite	7	5	19	<5
Clay Minerals	13	4	20	10
Analcime	6	1	7	5

highflow period, Evacuation Creek behaves as expected, with dissolved solids increasing as the water moves downstream. The baseflow pattern is unusual, however, in that dissolved solids apparently decrease moving downstream from Station S-6 to Station S-2. This change is not a result of dilution by higher-quality water, since streamflow shows a slight decrease, on the average, over this reach during baseflow. It is probable that this pehnomenon is a result of the interconnection between Evacuation Creek and the bird's nest aquifer, which occurs between these two stations; the aquifer system would act as a reservoir in reducing variations in water quality.

The relation between dissolved oxygen and temperature is also an important water-quality consideration. The saturation concentration of oxygen dissolved in water is influenced by elevation and water temperature. Elevations of the stations are constant, so that only temperature and dissolved oxygen (DO) are variables in this system. Unless oxygen is rapidly being produced or utilized within the stream, it will remain near the saturation level, since interchange with the atmosphere occurs freely. This is essentially what is shown by Figure II-47. A few times during the summer, DO concentrations in Evacuation Creek exceeded saturation (possibly as the result of photosynthetic oxygen production by algae) and during a few times in the winter, DO concentrations were well below saturation (perhaps because ice cover inhibited interchange with the atmosphere). Evacuation Creek DO concentrations averaged 91 percent of saturation and were above 7 mg/l 89 percent of the time. The White River was more consistent, with levels averaging 91 percent of saturation and were above 6 mg/l 98 percent of the time.

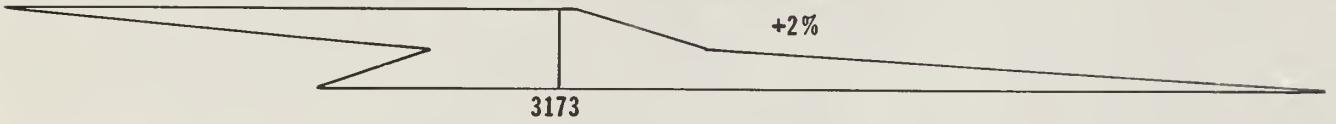
Since the ionic balances indicate that only concentrations of elements change with time and the distribution among elements remains fairly constant, there are several more relationships that can be discussed. Specific conductance and dissolved solids are two parameters that interrelate, since it is the free ions that carry current in aqueous solutions. The relationships developed between these two constituents using linear regression are shown in figures II-48 and II-49 for the White River and Evacuation Creek, respectively. Both relationships are as expected, since the slopes are between 0.54 and 0.96, with the higher value on Evacuation Creek corresponding to the higher sulfate levels (USGS, WSP 1473, 1970). Besides the relationship between general specific conductance and dissolved solids, it is possible to correlate individual ions with specific conductance and dissolved solids. The results of such an analysis are shown in tables II-13 and II-14 for the White River and Evacuation Creek, respectively.

S-1 WHITE RIVER ABOVE HELLS HOLE CANYON

-0.3%

264

S-7 EVACUATION CREEK BELOW PARK CANYON



+2%

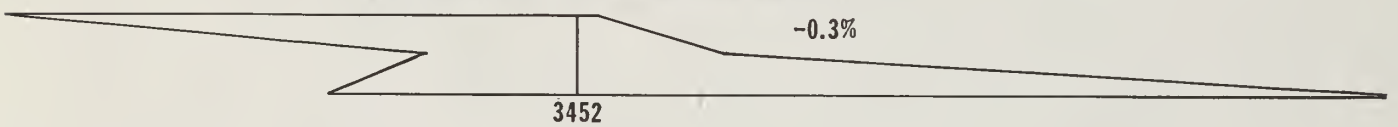
3173

S-6 EVACUATION CREEK AT WATSON, UTAH

-1%

3273

S-2 EVACUATION CREEK NEAR MOUTH



-0.3%

3452

S-3 WHITE RIVER NEAR WATSON, UTAH

-0.3%

272

S-4 WHITE RIVER ABOVE SOUTHAM CANYON

-1%

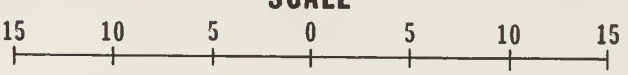
278

S-11 WHITE RIVER BELOW ASPHALT WASH

+1%

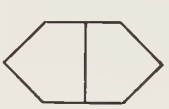
270

SCALE



(me/l) CATIONS (me/l) ANIONS

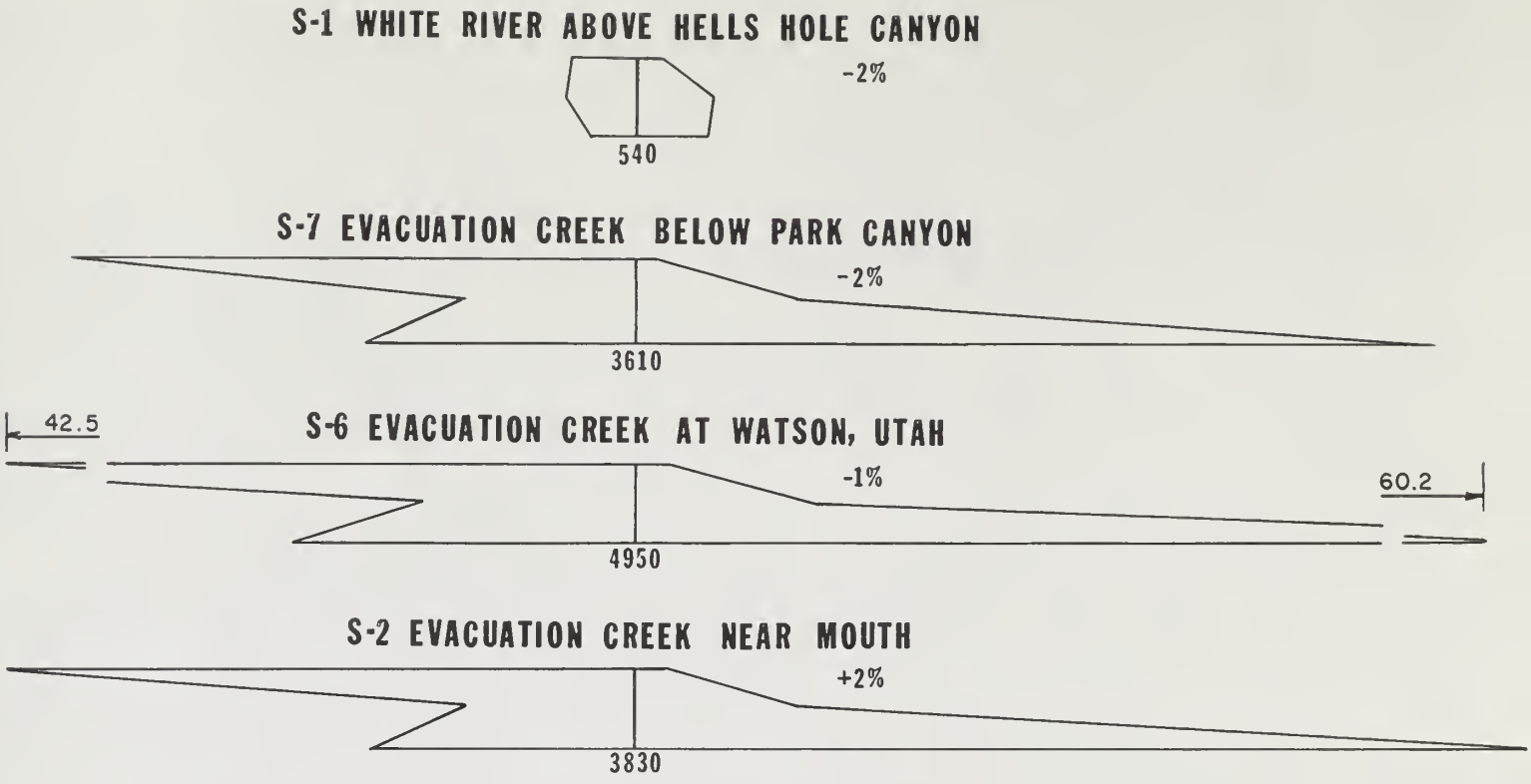
LEGEND



00% = PERCENT BY WHICH ANIONS EXCEED CATIONS

BALANCE AND DISTRIBUTION OF MAJOR IONS IN SURFACE WATER
HIGH FLOW PERIOD 1975 WATER YEAR
(MAY THRU JULY)

FIGURE II-45

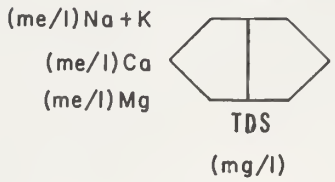


SCALE

15 10 5 0 5 10 15

(me/l) CATIONS (me/l) ANIONS

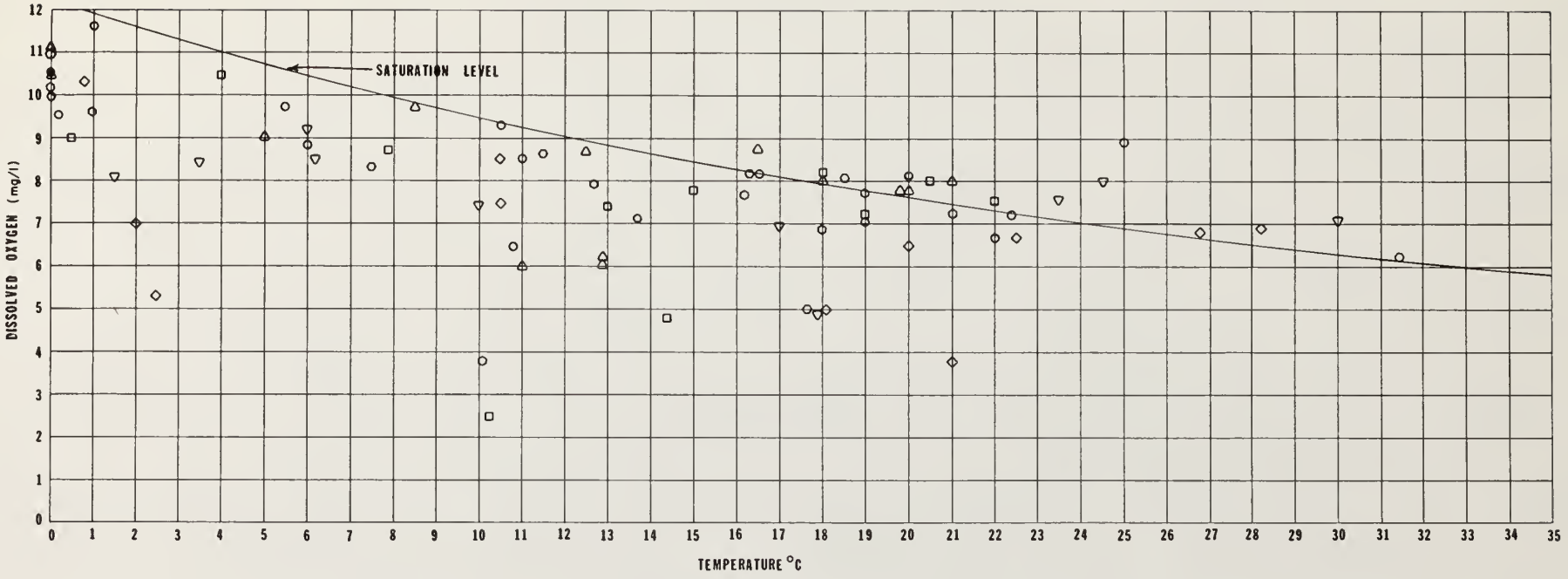
LEGEND



00% = PERCENT BY WHICH ANIONS EXCEED CATIONS

BALANCE AND DISTRIBUTION OF MAJOR IONS IN SURFACE WATER
BASE FLOW PERIOD 1975 WATER YEAR

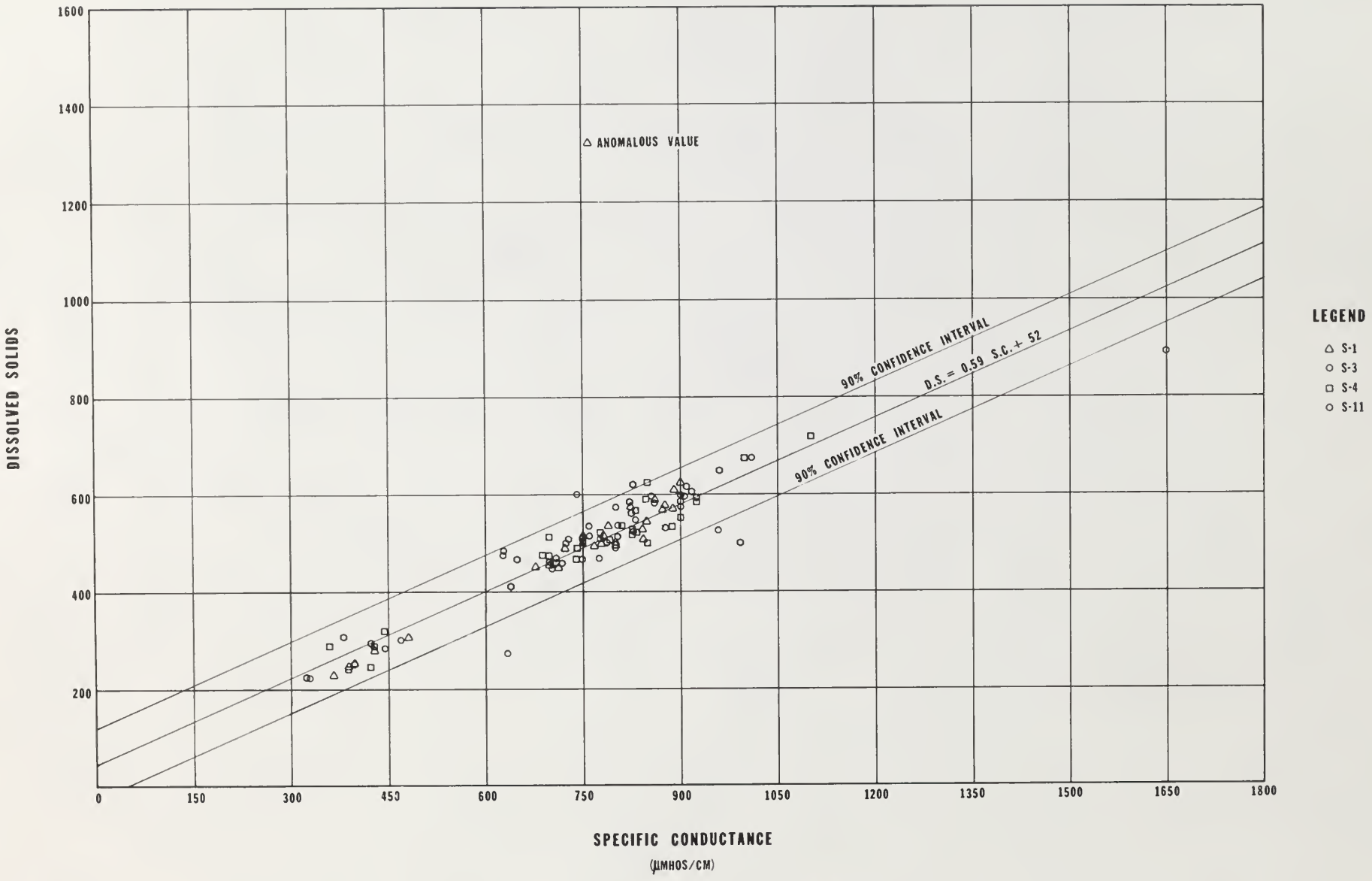
FIGURE II-46



RELATION BETWEEN TEMPERATURE AND DISSOLVED OXYGEN

AUGUST, 1974 - SEPTEMBER, 1975

FIGURE II-47

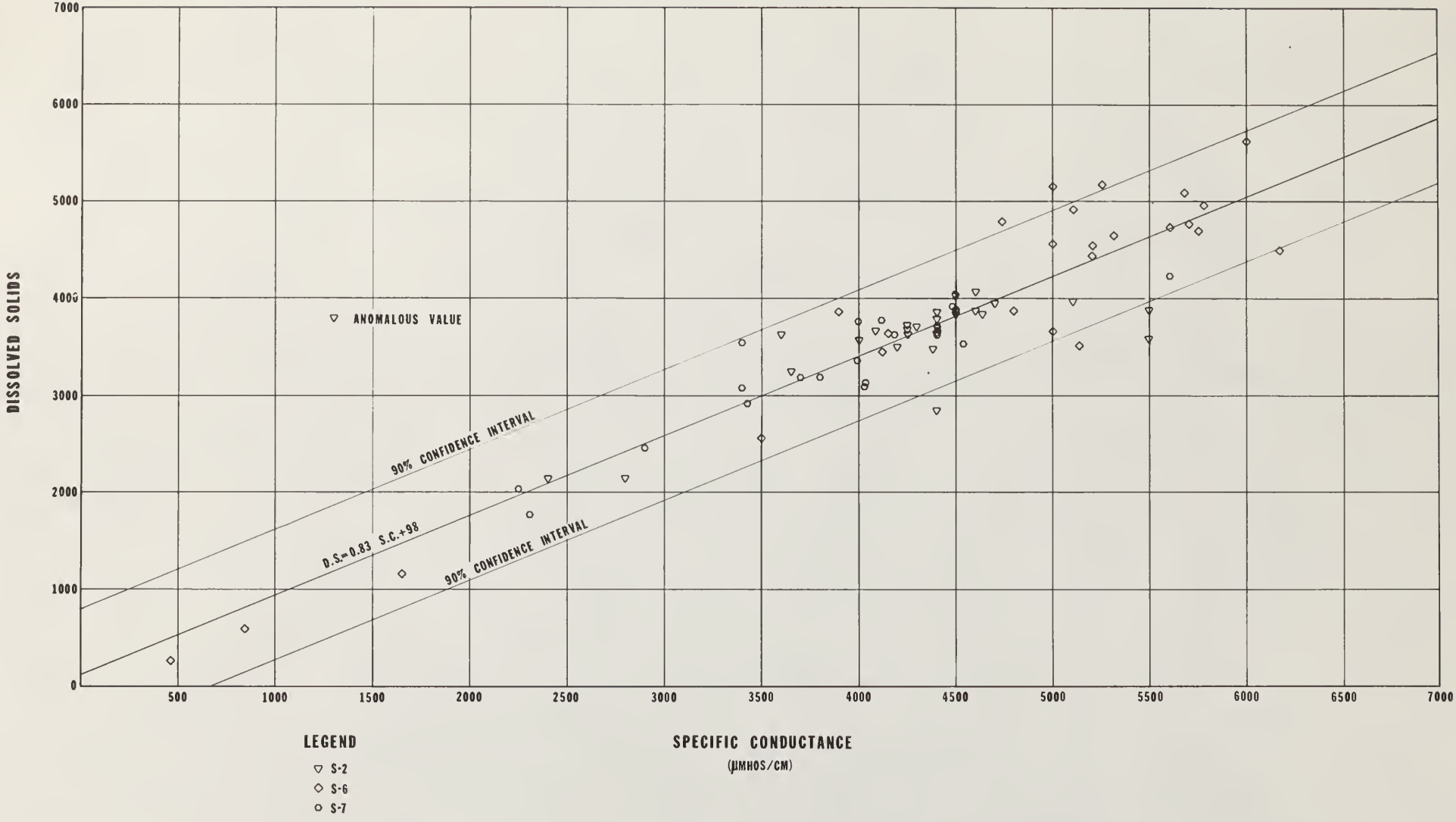


RELATION BETWEEN SPECIFIC CONDUCTANCE AND DISSOLVED SOLIDS

WHITE RIVER

AUGUST, 1974 - JANUARY, 1976

FIGURE II-48



RELATION BETWEEN SPECIFIC CONDUCTANCE AND DISSOLVED SOLIDS

EVACUATION CREEK
AUGUST, 1974 - JANUARY, 1976

FIGURE II-49

TABLE II-13

REGRESSION ANALYSIS RESULTS
EVACUATION CREEK WATER QUALITY DATA

Variable		Regression Line		Accuracy		
Independent	Dependent	Intercept	Slope	No. of Pairs	Correlation Coefficient	Standard Error of Estimate
Specific Conductance (µmhos/cm	Dissolved Solids (mg/l)	98	0.83	74	0.85	371.0
Dissolved Solids (mg/l)	Calcium (mg/l)	48	0.03	73	0.68	21.0
Dissolved Solids (mg/l)	Magnesium (mg/l)	6	0.04	75	0.91	13.0
"	Sodium	-33	0.20	75	0.97	36.0
"	Chloride (mg/l)	- 2	0.013	73	0.70	8.1
"	Sulfate (mg/l)	1964	0.030	73	0.05	563.0
"	Copper (mg/l)	29	-0.0001	44	0.01	93.0
"	Iron (mg/l)	118	-0.021	44	0.19	42.0
"	Molybdenum (mg/l)	9	0.007	45	0.25	12.0
"	Selenium (mg/l)	4	-0.0003	43	0.008	3.7

TABLE II-14

REGRESSION ANALYSIS RESULTS
WHITE RIVER WATER QUALITY DATA

Variable		Regression Line		Accuracy		
Independent	Dependent	Intercept	Slope	No. of Pairs	Correlation Coefficient	Standard Error of Estimate
Specific Conductance (µmhos/cm)	Dissolved Solids (mg/l)	52.0	0.590	109	0.90	38.00
Dissolved Solids	Calcium	23.0	0.840	112	0.74	5.90
Dissolved Solids	Magnesium	2.6	0.046	111	0.88	2.00
"	Sodium	-28.0	0.190	111	0.90	7.10
"	Chloride	- 5.0	0.086	113	0.24	21.00
"	Sulfate	38.0	0.247	113	0.64	26.00
"	Copper	-15.0	0.061	67	0.02	50.00
"	Iron	66.0	0.060	63	0.03	44.00
"	Molybdenum	1.0	0.003	67	0.099	1.14
"	Selenium	- 1.0	0.0037	60	0.37	0.54

The high correlation coefficients and low standard error of estimated values indicate that there is a definite relationship between dissolved solids and specific conductance and between dissolved solids and magnesium, sodium, and calcium in the White River; and between dissolved solids and specific conductance, and between dissolved solids and magnesium, calcium, chloride, and sodium in Evacuation Creek. The relationships between the other elements are poor to nonexistent. Although the regression relationships are poorly defined (low correlation coefficients), it is still possible to use the equations to predict with reasonable certainty the concentrations of molybdenum, sulfate, and selenium in the White River and molybdenum in Evacuation Creek because the standard errors of estimate are relatively low. Besides using regression analysis, it is possible to predict most element concentrations during highflow and low-flow periods from the record, since most elements show consistency within each period. The means and standard deviations for concentrations of most elements during these two periods at the gauging sites on Evacuation Creek and the White River are shown in Appendices II-1 through II-23, along with summaries of the Utah Water Quality Standards, USPHS Drinking Water Standards, and the NAS Water Quality Criteria.

Typical Rainfall-Runoff Event May 28-30, 1975

One of the periods of highest runoff for Evacuation Creek occurred from May 28 to May 30, 1975 as the result of a rainstorm. The isohyetal map (Figure II-50) shows the rainfall pattern across the tracts on May 28, 1975, when up to 0.90 in. of precipitation fell. The variations in itensity are evident on this map, which shows two storm centers, one over Evacuation Creek and one over Southam Canyon. Most thunderstorms in this area travel northeast, a direction the May 28 storm appears to follow. Precipitation outside of the study area for Evacuation Creek basin is monitored by only one USGS gauge located on Evacuation Creek above the mouth of Missouri Creek. It was estimated that about 0.25 in. of precipitation fell at this gauge on May 28. Smaller amounts of precipitation fell on May 29 throughout the tract, as is evident in the double peaks on the hydrograph (Figure II-51).

No runoff was recorded at either Thimble Canyon (Station S-8) or the Evacuation Creek tributary near Watson (Station S-15) and it was presumed that most of the runoff was from the area immediately adjacent to the stream. The recession curve after the second peak on Figure II-51 is typical of stream gauges in sandy channels in this area.

Sedimentation blocked the stream-gauge stilling well causing a delayed recession curve record because the recorder float inside the gauge remained higher than the stream during this period. Conductance was generally inversely proportional to flow, while temperature followed the diurnal air temperature pattern. Figure II-52 shows the runoff hydrograph for this period at Station S-11 on the White River. There are four major peaks in flow on the White River instead of the two peaks on Evacuation Creek. The White River has more peaks because of discharges from other canyons. The peaks on the White River that correspond to flows from Evacuation Creek are not nearly as pronounced as they were on Evacuation Creek because of attenuation and the higher normal flow of the White River but are of similar magnitude. Approximately four hours are required for peak discharges at Station S-7 in Evacuation Creek to reach Station S-11 on the White River. Since the distance between these points is about 19 km (12 mi), this represents a flow velocity of about 0.9 m/s (3 ft/sec). While specific conductance of the White River was inversely proportional to flow on May 28, this recording may be inaccurate because the recorder appears to have been malfunctioning at the time. Temperature patterns had no individual peaks because, as with conductance, the runoff was absorbed by the flow of the White River.

LEGEND

ELEVATION

- 1463-1524 METERS(4800-5000 FT.)
- 1524-1585 METERS(5000-5200 FT.)
- 1585-1646 METERS(5200-5400 FT.)
- 1646-1707 METERS(5400-5600 FT.)
- 1707-1768 METERS(5600-5800 FT.)
- 1768-1829 METERS(5800-6000 FT.)
- 1829-1890 METERS(6000-6200 FT.)

WATERSHED BOUNDARY

00 (0.0) PRECIPITATION ISOHYETAL

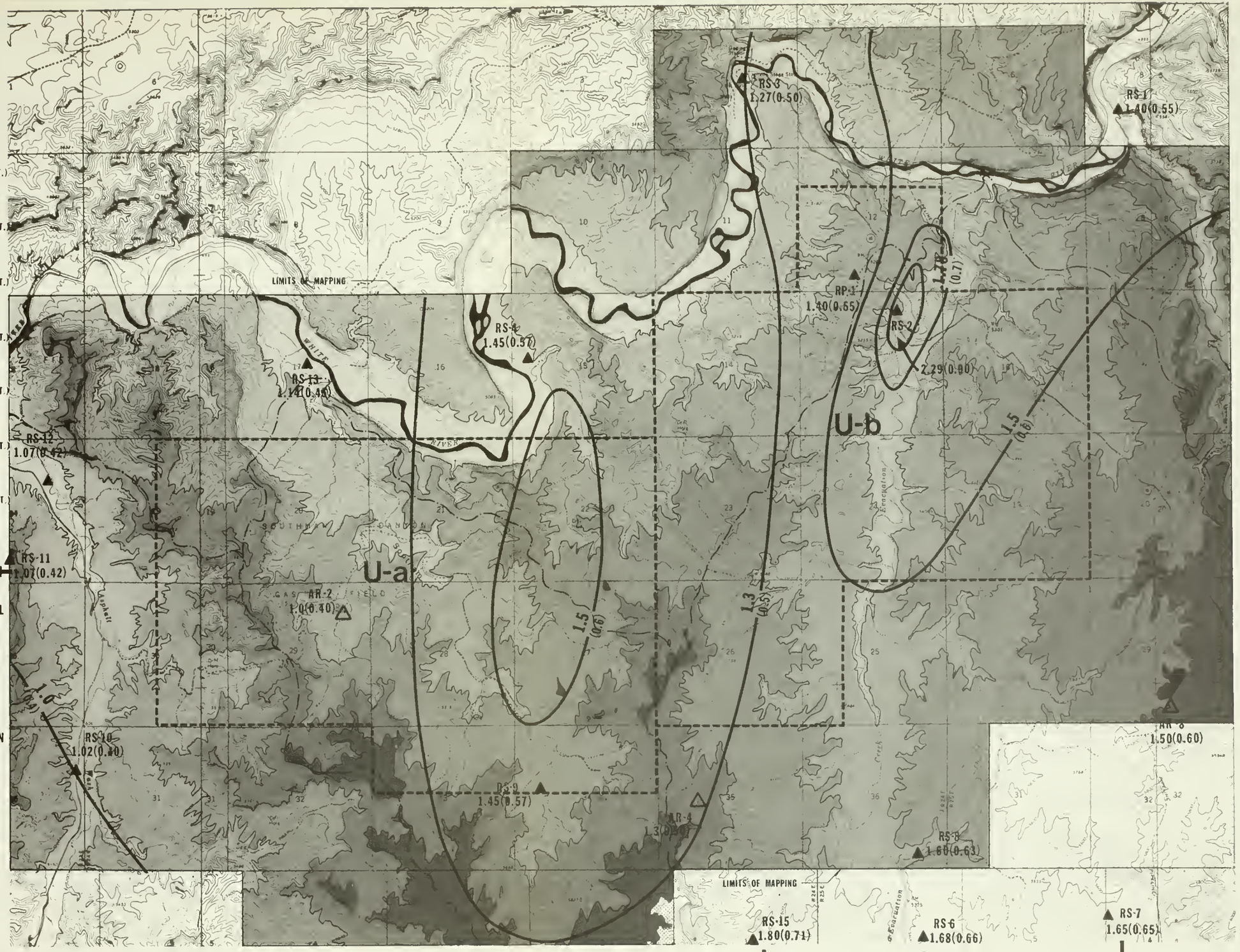
▲ MANUAL PRECIPITATION GAUGES CM(IN) MAY 28, 1975

△ AUTOMATIC PRECIPITATION GAUGES CM(IN) MAY 28, 1975

N

2000 0 2000

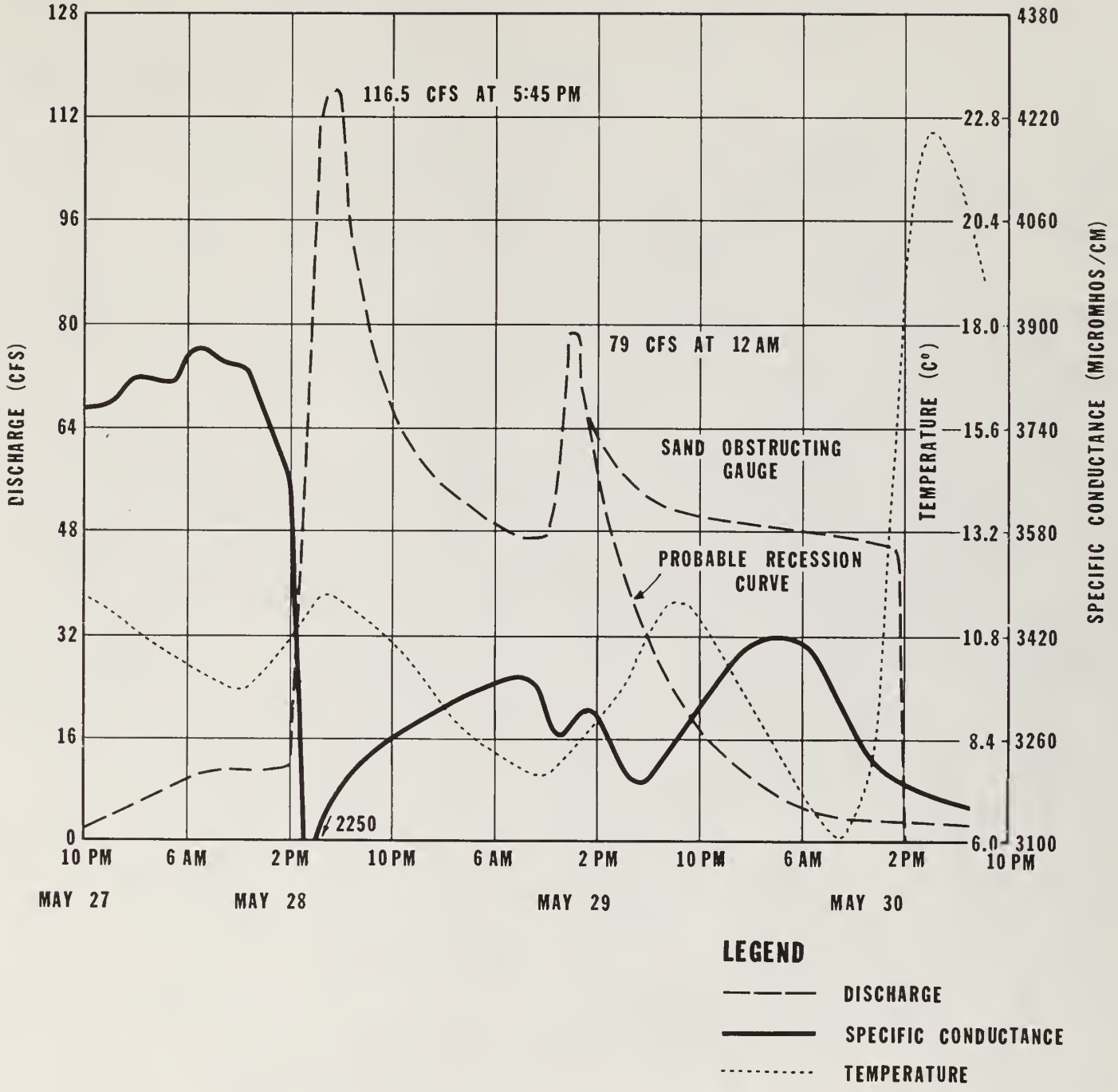
SCALE IN FEET



ISOHYETAL MAP

MAY 28, 1975
CM(IN)

FIGURE II-50

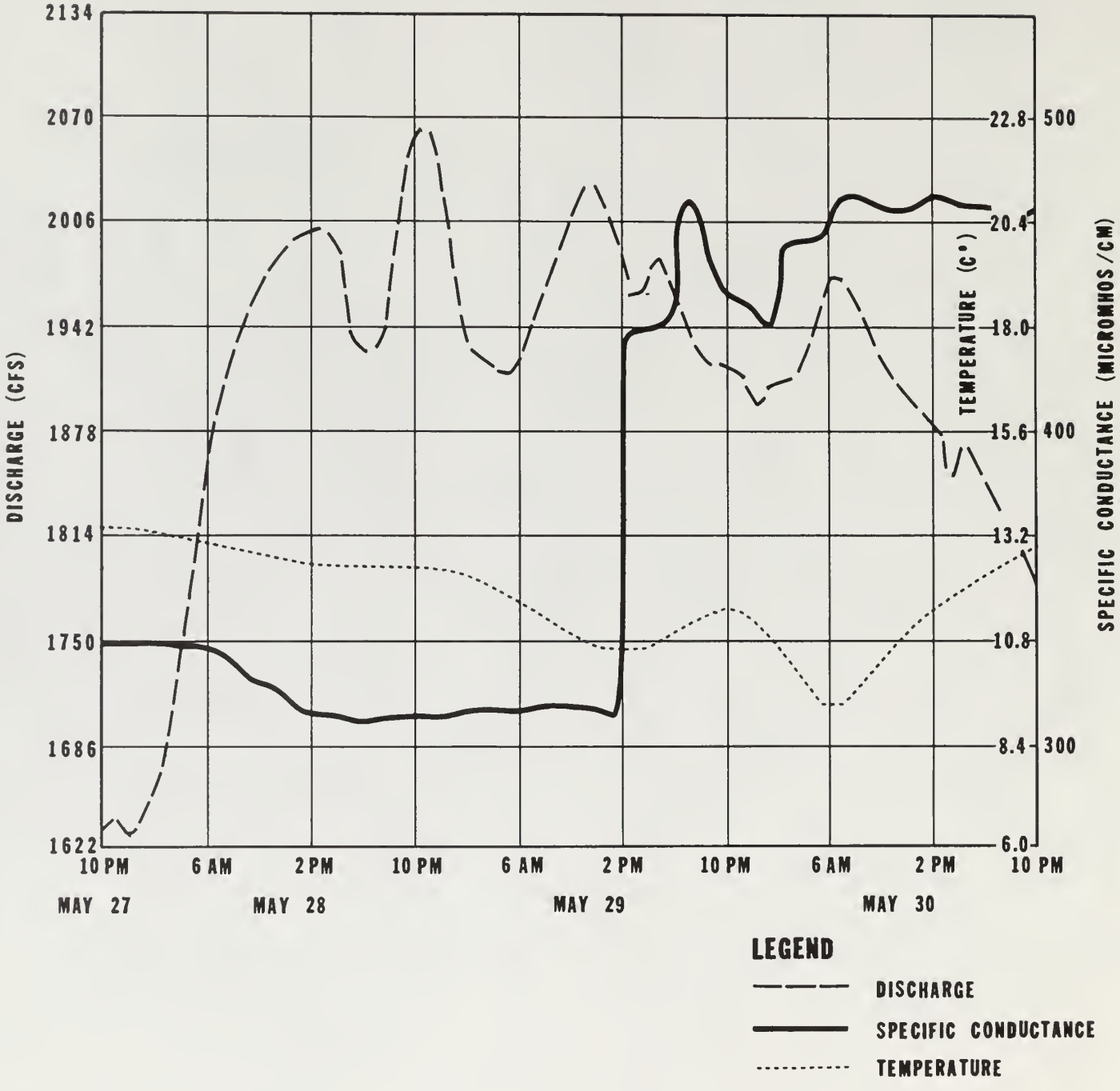


HOURLY DISCHARGE, TEMPERATURE & CONDUCTANCE

EVACUATION CREEK NEAR MOUTH (S-2)

MAY 27, 1975 TO MAY 30, 1975

FIGURE II-51



HOURLY DISCHARGE, TEMPERATURE & CONDUCTANCE

WHITE RIVER BELOW ASPHALT WASH (S-11)

MAY 27, 1975 TO MAY 30, 1975

FIGURE II-52

2. GROUND WATER HYDROLOGY

a. Ground Water Occurrence

Although no ground water was encountered in the Uinta Formation during the drilling program, ground water was encountered throughout the region in alluvial deposits along major stream courses and throughout the Green River, Wasatch, and Mesa Verde formations (Austin and Skogerboe 1970). The Green River Formation, especially its upper-most member, the Parachute Creek Member, contains the principal oil-shale zone, and therefore most of the deeper wells were drilled to investigate this zone. Data from the deeper horizons on and around the tracts are available in geophysical logs of oil-test and gas-test wells.

Figure II-53 illustrates the potential water-bearing zones throughout the penetrated column. The log is generally typical of the region on and near the tracts. The principal aquifer (bird's nest aquifer) investigated as part of the baseline program occurs at the top of the Parachute Creek Member of the Green River Formation, as shown on Figure II-53. The deep oil-test and gas-test wells used to locate the bird's nest aquifer penetrate beyond this aquifer and have a higher static head than would be expected by projecting gradients outward from the tracts. These wells, therefore, are not useful as indicators of the regional potentiometric surface, although they provide information about the occurrence and physical characteristics of the principal aquifer.

Uinta Formation

Although water has been encountered elsewhere in the Uinta Formation, none was encountered on the tracts during the on-tract drilling program; however, Austin and Skogerboe (1970) cite several examples of water in the formation in the form of springs and wells. On the tracts, isolated, short-lived seeps have been observed issuing from fractures and bedding planes during spring.

Green River Formation

The Parachute Creek, Garden Gulch, and Douglas Creek Members of the Green River Formation appear to contain water, as determined from inspection of deep oil-test and gas-test wells; however, only two wells drilled for the baseline monitoring program were completed deeper than the lower part of the Parachute Creek Member. Austin and Skogerboe (1970) mention encountering water in the Green River Formation but do not specify where in the stratigraphic section the data were collected.

The location of a major water-bearing zone at the top of the Parachute Creek Member is shown on Figure II-53. Thin oil shales and fine sands conceal any significant water occurrences from there to a depth of about 305 m (1,000 ft). From about 305 m (1,000 ft) to the base of the member, two thin and widely separated sandy zones probably contain water.

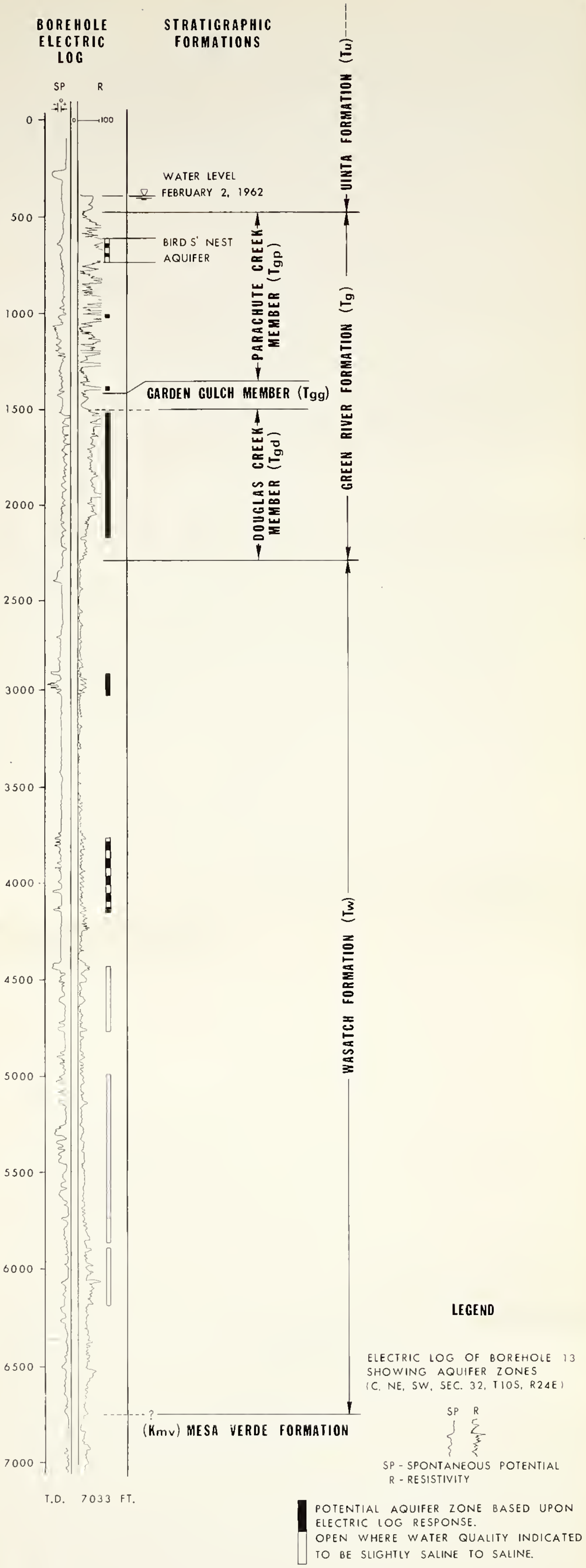
The Garden Gulch Member is shaley and, as shown on geophysical logs (Figure II-53), does not contain a significant amount of water. The Douglas Creek Member demonstrates high resistivity throughout its depth and could be the most consistent water-bearing unit throughout its depth of any member above the Mesa Verde Formation.

Wasatch Formation

Electric logs (Figure II-53) of deep test wells indicate the presence of water in the Wasatch Formation, especially in its upper half. The formation contains water-bearing sands throughout its first 640 m (2,100 ft). A sandy zone extends from about 1,342 m (4,400 ft) to about 1,754 m (5,750 ft) of the formation, and predominantly shale extends to the base. Nearly all the sands in the formation appear to contain water, but spontaneous potential (SP) and resistivity curves indicate that the water quality may vary widely.

Mesa Verde Formation

Most of the deep oil-test and gas-test wells discussed in this report penetrate the upper 30.5 m to 61 m (100 ft to 200 ft) of the Mesa Verde Formation. The logs show no strong indications of water.



TYPICAL BOREHOLE ELECTRIC LOG OF ROCK FORMATIONS BENEATH THE SITE

FIGURE II-53

b. Aquifers

The principal aquifer investigated in the region is described by Cashion and Brown (1956) as a stratigraphic unit near the top of the Green River Formation:

> "Many cavities, some of which contain secondary calcite and which are believed to have been formed by the leaching of nahcolite from the marlstone, occur in a zone of the upper part of the Evacuation Creek Member. The zone is locally called the "bird's nest zone" and is well developed near the mouth of Evacuation Creek."

Cashion (1974) later dropped the term "Evacuation Creek Member" and extended the term "Parachute Creek Member" to include the top of the Green River Formation. His discussion of the upper part of the Parachute Creek Member includes this description: "Upper part contains small pods and lenses of nahcolite ($NaHCO_3$) as indicated by solution cavities on outcrop." The term "bird's nest" will be retained for this report and will include the bird's nest aquifer, the principal aquifer investigated in the region.

Outcrops of the bird's nest aquifer were investigated and found to consist of irregularly-spaced elliptical cavities ranging in length (measured along the long axis) from a few centimeters to slightly more than 30.5 cm (1 ft). The long axes of these elliptical cavities are parallel to the plane of bedding, and their depth on outcrop is rarely more than 20.3 cm (8 in.) but may exceed several meters. Ground water seepage from the cavities is common along Evacuation Creek (Figure II-54). (See the fourth quarterly report for a comprehensive discussion of this aquifer.)

It is surprising that although the aquifer originally consisted of nahcolite nodules set in marlstone, it is very persistent laterally and vertically throughout the area investigated (Figure II-55). The thickness of the aquifer ranges from 27.4 m to 62.5 m (90 ft to 205 ft), with an average thickness of about 35 m (115 ft), as shown on Table II-15. On electric logs the bird's nest aquifer appears uniform throughout the area investigated. It consists of two zones of high resistivity separated by an interval of low resistivity. This low resistivity zone commonly occurs in the upper one third of the aquifer and is usually 4.6 m to 5.3 m (15 ft to 20 ft) thick (Figure II-53). The highest resistivity zone--equated with the Horse Bench Sandstone of Cashion (1974)--may be observed on outcrop in Evacuation Creek Canyon.

TABLE II-15

REGIONAL AQUIFER DATA, BIRDS NEST AQUIFER NEAR THE TOP OF THE GREEN RIVER FORMATION, SOUTHEAST UINTA BASIN, UTAH

Well* No.	Location	Surf. Elevation	Aquifer Interval (Depth in Ft.)	Aquifer Thickness (Ft.)	Elev. Top Of Aquifer	Well Depth (Ft.)	Operator	Data Available in Aquifer Zone: Log. Electric	Gamma Ray	Neutron	Caliper	Formation Density	Senic.	Temp.	Flow
2	C NW SE 24-9S/23E	5645	1356-1478	122	4280	7236	Pacific Nat. Gas	X	X	X	X	X	X		
3	NW SE 02-10S/23E	5461	1545-1660	115	3916	5226	Humble Oil		X	X					
4	NW NE NE 11-10S/23E	5492	1430-1520	90	4062	5049	El Paso Nat. Gas. Co.	X							
5	NE NE NW 14-10S/23E	5587	1345-1550	205	4242	8502	Gulf Oil Corp.	X	X	X					
6	NE NE SE 15-10S/23E	5613	1410-1575	165	4203	7418	El Paso Nat. Gas Co.	X	X	X					
7	NW NW 24-10S/23E	4932	520-640	120	4412	6486	Shell Oil Co.	X	X				X		
8	NE NE 36-10S/23E	5078	370-500	130	4708	924	Shell Oil Co.	X							
9	NE SW 03-19S/23E	5334	1415-1535	120	3919	5858	Belco Pet. Corp.	X					X		
10	NW NE SE 30-10S/24E	5294	602-710	108	4692	1141	White R. Sh. Project	X		X	X	X	X	X	X
11	SW SE 28-10S/24E	5392	514-620	106	4878	7048	El Paso Nat. Gas	X			X				
12	NE NE 29-10S/24E	5260	542-660	118	4718	6030	El Paso Nat. Gas	X			X				
13	C NE SW 32-10S/24E	5480	610-715	105	4870	7033	Shell Oil Co.	X					X		
14	NE SW 22-10S/24E	5292	490-695	115	4802	6161	Moab Drilling Co.	X			X		X		
15	S/2 SW SW 14-10S/24E	5242	408-522	114	4834	958	White River Sh. Project	X	X	X	X	X	X	X	X
16	SW NW 24-10S/24E	5417	380-515	135	5037	4249	Continental Oil Co.	X	X	X					
20	NW NW SW 02-11S/23E	5550	620-740	120	4930	8038	Gen. Pet. & Stanolind	X							
22	NW SE 11-11S/23E	5989	890-1000	110	5099	5901	Shamrock Oil & Gas. Co.	X							
23	SW SE 13-11S/23E	5617	325-455	130	5292	5863	Shamrock Oil & Gas Co.	X							
24	SE NW 14-11S/23E	5958	875-1000	125	5083	6649	Shamrock Oil & Gas Co.	X							
25	SE SE 10-11S/23E	5849	762-900	138	5087	7384	Shamrock Oil & Gas Co.	X							
28	NE SW 18-11S/24E	5567	275-400	125	5292	5581	Shamrock Oil & Gas. Co.	X							
29	SE SE 15-11S/23E	6076	872-970	98	5204	6467	Shamrock Oil & Gas Co.	X							
30	NE SW 03-11S/24E	5270	211-310	99	5059	2521	Shamrock Oil & Gas Co.	X							
X-9	NW SE SW 27-10S/24E	5427	553-651	98	4874	1068	White R. Sh. Project	X	X	X	X	X	X	X	X
G-19	SE NE NW 14-11S/24E	5832	190-325	135	5642	800	White R. Sh. Project		X	X	X	X			
X-2	NW NE NW 14-10S/24E	4984	213-326	113	4771	766	White R. Sh. Project	X	X	X	X	X		X	X
P-3	SE SE SW 26-10S/24E	5498	370-480	110	5128	711	White R. Sh. Project	X	X	X	X	X		X	X
P-1	NE SE SW 12-10S/24E	5281	300-435	135	4984	1225	White R. Sh. Project	X	X	X	X	X		X	X
X-3	C NE NW 18-10S/25E	5295	90-260	170	5205	586	White R. Sh. Project	X	X	X	X	X	X	X	X
X-6	C NW 19-10S/25E	5472	274-379	105	5198	806	White R. Sh. Project	X	X	X	X	X	X	X	X
P-4	NE SE SE 19-10S/25E	5719	346-482	136	5343	1170	White R. Sh. Project		X	X	X	X			
HS-4	NW NE NW 20-10S/24E	5061	495-667	172	4566	1076	Gulf Oil Corp	X	X	X					
P-2	NW NE NE 20-10S/24E	4991	404-500	96	4587	1290	White R. Sh. Project	X	X	X	X	X	X	X	X

*Feet above mean sea level

*1-30 & HS designates wells of record not drilled for the baseline data collection program.
X,G,P designates wells of record drilled for the baseline data collection program.

LEGEND

SALT DEPOSITS WHICH INDICATE EVIDENCE OF GROUND WATER SEEPAGE

FLOWING SPRINGS

EPHEMERAL STREAM

DRY WASH

MEASUREMENTS OF TEMPERATURE AND SPECIFIC CONDUCTANCE

- EVACUATION CREEK (SHOWN EAST OF CREEK)

- SPRINGS FROM BIRDS NEST AQUIFER (SHOWN WEST OF CREEK)

DATE AND TIME
5/8,1725
16.3—TEMPERATURE, IN DEGREES CELSIUS
4700
SPECIFIC CONDUCTANCE, IN MICROHMS/CM

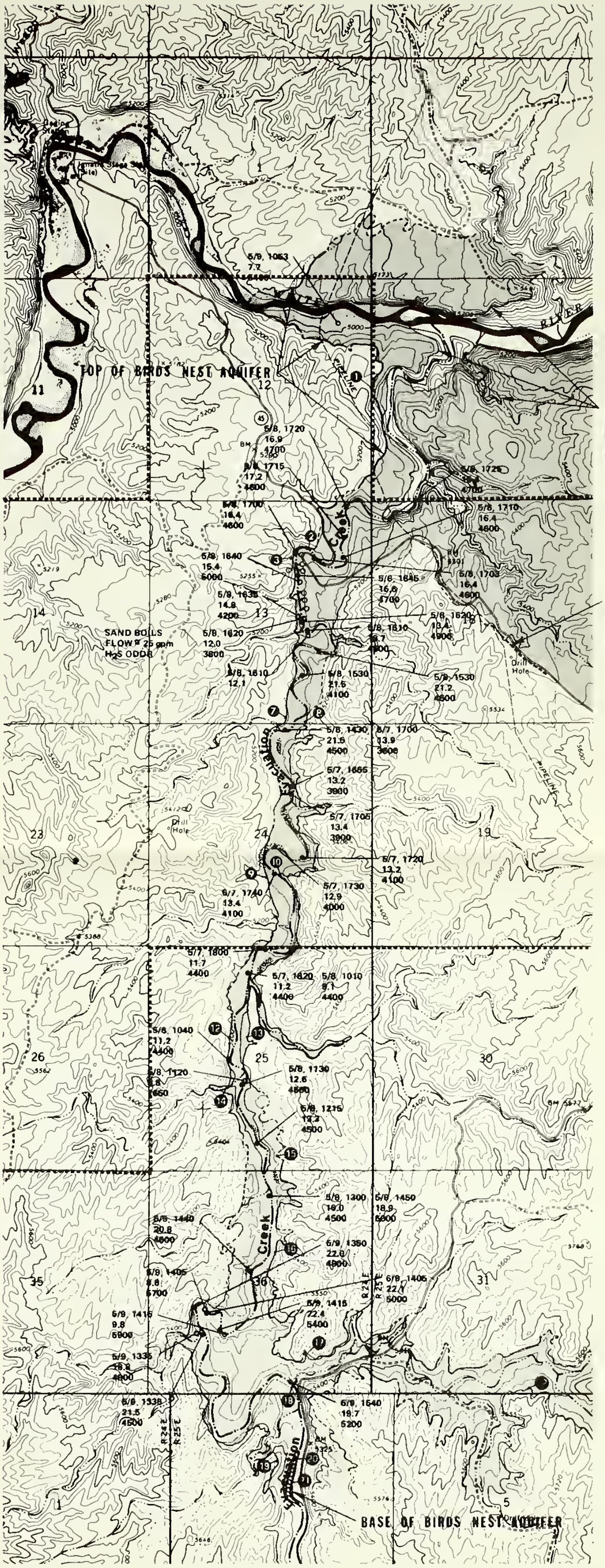
ELEVATION POINTS ALONG THE BIRDS NEST AQUIFER

❶ ELEVATION POINT ON BIRDS NEST AQUIFER CONTACT, WITH STATION NUMBER

POINT	ELEVATION	LOCATION		DESCRIPTION
EP 1	5183.5	N602,270	E2,657,920	Top of Aquifer
EP 2	5118.0	N598,645	E2,656,522	Top of Aquifer Near steep edge
EP 3	5099.5	N598,410	E2,656,170	Top of Aquifer Near steep edge
EP 4 (X-3)	5295.5	N598,774	E2,659,572	
EP 5	5130.0	N596,862	E2,656,305	
EP 6	5167.0	N596,780	E2,657,243	
EP 7	5119.5	N594,550	E2,656,174	
EP 8	5147.5	N594,500	E2,656,570	
EP 9	5177.2	N590,755	E2,655,718	
EP 10	5168.8	N590,842	E2,656,100	
EP 11	5191.0	N588,335	E2,655,470	
EP 12	5212.0	N585,954	E2,654,994	
EP 13	5221.0	N585,965	E2,655,445	
EP 14	5229.0	N585,795	E2,655,011	
EP 15	5292.0	N584,152	E2,656,200	
EP 16	5323.5	N581,905	E2,656,277	On Steep Edge
EP 17	5417.5	N579,522	E2,657,012	
EP 18	5426.5	N578,560	E2,657,151	
EP 19	5425.0	N577,080	E2,656,534	
EP 20	5307.0	N577,010	E2,656,895	
EP 21	5315.0	N576,500	E2,656,821	
EP 22_1	5088.0	N601,028	E2,658,999	Base of Aquifer Steep edge
EP 22_2	5560.0	N578,805	E2,662,270	
EP 23	5086.0	N603,405	E2,659,450	Base of Aquifer

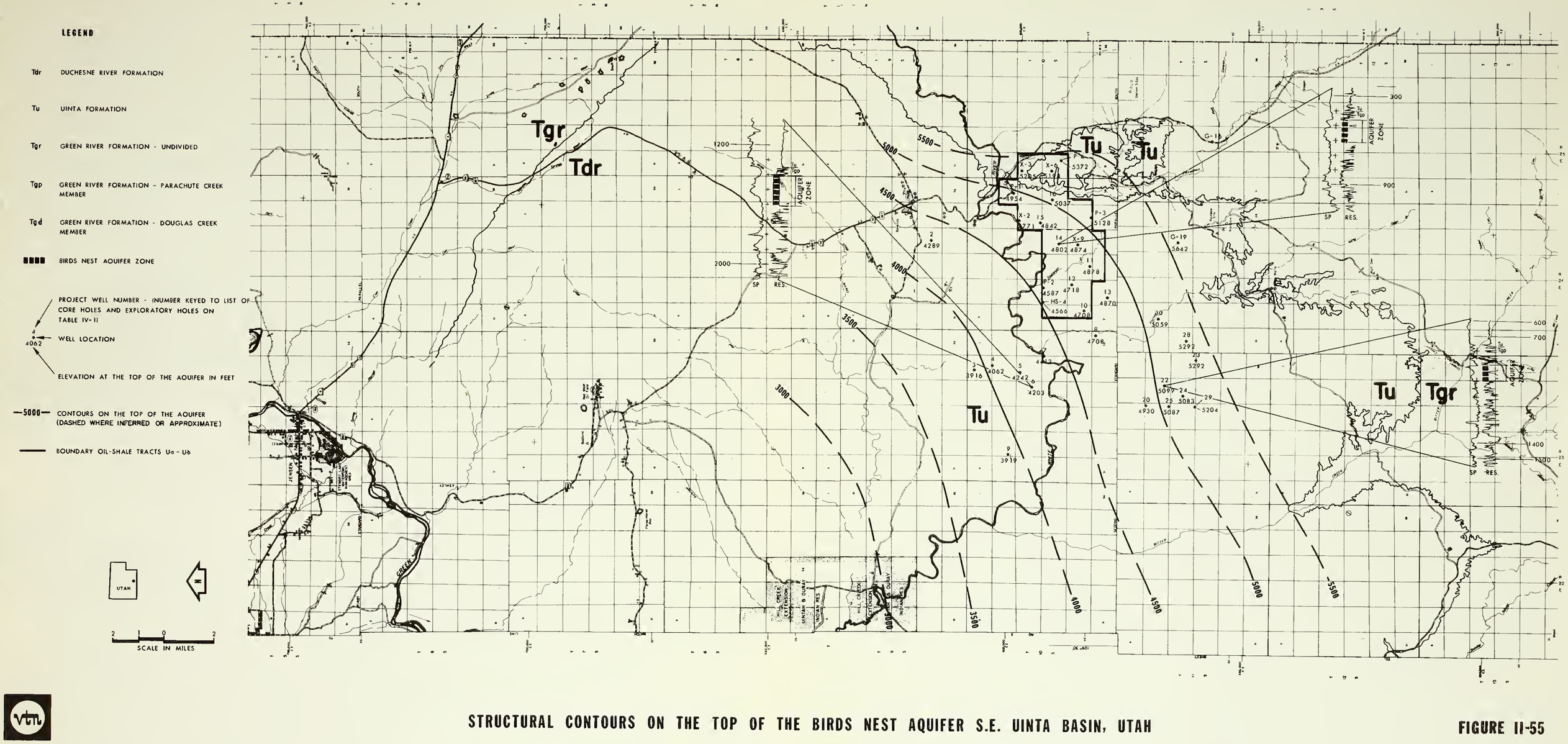
OIL SHALE TRACTS U-a & U-b BOUNDARIES

2000 0 2000
SCALE IN FEET



HYDROGEOLOGIC MAP OF EVACUATION CREEK, TRACTS U-a & U-b

FIGURE 11-54


LEGEND
Tdr DUCHESNE RIVER FORMATION
Tu UINTA FORMATION
Tgr GREEN RIVER FORMATION - UNDIVIDED
Tgp GREEN RIVER FORMATION - PARACHUTE CREEK MEMBER
Tgd GREEN RIVER FORMATION - DOUGLAS CREEK MEMBER
BIRDS NEST AQUIFER ZONE
PROJECT WELL NUMBER - (NUMBER KEYED TO LIST OF CORE HOLES AND EXPLORATORY HOLES ON TABLE IV-11
4062 WELL LOCATION
ELEVATION AT THE TOP OF THE AQUIFER IN FEET
—5000— CONTOURS ON THE TOP OF THE AQUIFER (DASHED WHERE INFERRED OR APPROXIMATE)
BOUNDARY OIL-SHALE TRACTS Ua - Ub
UTAH
N
2 1 0 2
SCALE IN MILES
Tgr
Tdr
Tu
Tu
Tu
Tu
Tgr
AQUIFER ZONE
SP RES.
GREEN RIVER
HILL CREEK EXTENSION
UINTAH & OURAY INDIAN RES

STRUCTURAL CONTOURS ON THE TOP OF THE BIRDS NEST AQUIFER S.E. UINTA BASIN, UTAH

FIGURE II-55

The stratigraphic position of the aquifer is as predictable as its physical properties. The aquifer occurs in the top 15.2 m to 38.1 m (50 ft to 125 ft) of the Green River Formation and is an average of 131 m (430 ft) above the mahogany marker (Figure II-55). The variability in the observed depth from the top of the aquifer may be explained by the soft-sediment deformational features at the contact of the Uinta and Green River formations.

Hydraulic Properties

Water-production figures of off-tract wells were not available. Flume-measured flow rates recorded during drilling on the tracts ranged from 0 to 44.1 liters/sec. (700 gallons per minute [gpm]) and averaged about 1.9 l/s (30 gpm). The varied production rates are closely linked to the presence or absence of artesian head on the aquifer, or in the case of the water table, to the degree of saturation. The bird's nest aquifer ranges from dry near the southeast corner of Tract U-b to about 76 m (250 ft) of artesian head at the northwestern edge of Tract U-a (Figure II-56). The large portion of dry aquifer east of Evacuation Creek was drained because Evacuation Creek and associated tributaries have incised below the base of the aquifer.

During early summer and mid-summer 1975, aquifer tests were conducted at the P-1, P-2 upper, P-2 lower, and P-3 sites, and the field data and data plots were reported to the Area Oil Shale Supervisor's Office (AOSO).

Table II-16 summarizes the values calculated from the test data. As indicated on Table II-16, transmissivities calculated for each site varied considerably. At each site, the transmissivities varied depending on the method of calculating and graphing of such variables as drawdown versus radius, recovery versus t/t', and drawdown versus time. In addition, transmissivity figures depended on the portion of the curve selected for the calculation. These variations in calculated transmissivity values illustrate that the hydraulic properties of the bird's nest aquifer depart from the perfect aquifer assumed in the usual methods of calculation. Because the bird's nest aquifer is not homogeneous or isotropic and because it does not have a flat water surface, late slope portions of drawdown curves (and drawdown versus radius techniques) are considered more valid indicators of true transmissivity than are early slope portions of the curves.

The testing program was originally designed to test at the highest possible rate of production for a sufficient length of time to allow the drawdown cone to expand to its ultimate

TABLE II-16

AQUIFER PUMP TEST RESULTS

	Observation Well Distance From Pumping Well(r) in ft.	Observation Well Designation	Method of Analysis	Period of Test	Calculated Aquifer Coefficients: Transmissibility (T) gallons/day/ft.	Calculated Aquifer Coefficients: Storage
P-1 Test Q = 45 gpm Duration of Pumping = 1800 min.	---	P-1 Pump	Time - Drawdown (Jacob)	Pumping	2475 (early slope) 1458 (late slope)	--- ---
	52.0	P-1 Pilot	Time - Drawdown (Jacob)	Pumping	914 (early slope) 1627 (late slope)	3.35×10^{-4} ---
			Residual Drawdown	Recovery	972	---
			Calculated Recovery Drawdown vs. Radius		1024 1800	3.40×10^{-4}
	101.5	P-1 Core	Time - Drawdown (Jacob)	Pumping	1789	3.80×10^{-4}
			Residual Drawdown	Recovery	1584	---
P-2 Upper Test Q = 10 gpm Duration of Pumping = 1676 min.		P-2 Upper Pump	Time - Drawdown (Jacob)	Pumping	120 (early slope) 27 (middle slope) 15 (late slope)	--- --- ---
	48.0	P-2 Upper Pilot	Time - Drawdown (Jacob)	Pumping	120 (early slope) 27 (middle slope) 15 (late slope)	1.6×10^{-5} --- ---
			Residual Drawdown	Recovery	25 (middle slope)	---
	98.0	P-2 Upper Core	Time- Drawdown (Jacob)	Pumping	123 (early slope) 36 (middle slope) 17 (late slope)	1.07×10^{-5} --- ---
			Residual Drawdown	Recovery	28 (middle slope)	---

LEGEND

(METERS) —15.2— (FEET)	CONTOURS ON THE GROUND WATER SURFACE ABOVE OR BELOW THE TOP OF THE BIRDS NEST AQUIFER. DASHED WHERE INFERRED.
⊙ S	SURFACE WATER MONITORING STATION
⊙ P	PILOT TEST HOLE (WATER)
⊙ G	GROUND WATER MONITORING STATION
⊙ HE	EXISTING GEOLOGIC CORE HOLE, EVACUATION
⊙ HS	EXISTING GEOLOGIC CORE HOLE, SOUTHAM
⊙ X	EXPLORATION GEOLOGIC CORE HOLE
⊙ AG	ALLUVIAL WELL (WATER)
△ AR	PRECIPITATION, AUTO (WATER)
▲ RS	PRECIPITATION, STORAGE (WATER)
× EVP	EVAPORATION PAN (WATER)

UTAH

N

1 0 1

SCALE IN MILES

WHITE RIVER SHALE PROJECT

BIRDS NEST AQUIFER

WATER TABLE AND ARTESIAN CONDITIONS

(ADJUSTED TO DEC. 1974 WATER LEVELS)

EASTERN UINTA BASIN, UTAH

FIGURE II-56

TABLE II-16 (Cont.)

	Observation Well Distance From Pumping Well(r) in ft.	Observation Well Designation	Method of Analysis	Period of Test	Calculated Aquifer Coefficients: Transmissibility (T) gallons/day/ft.	Calculated Aquifer Coefficients: Storage
		P-2 Lower Pump		Pumping	---	---
				Recovery	---	---
	48.6	P-2 Lower Pilot	Time - Drawdown (Jacob)	Pumping	62,586 (early slope) 111,692 (late slope)	6.77×10^{-6} ---
			Calculated Recovery	Recovery	69,173	1.14×10^{-5}
P-2 Lower Test			Residual Drawdown		69,173	---
Q = 550 gpm			Time - Drawdown (Jacob)	Pumping	63,130 (early slope) 103,714 (late slope)	8.29×10^{-5} ---
Duration of Pumping = 8765 min.	94.9	P-2 Lower Core	Calculated Recovery	Recovery	68,514	3.13×10^{-5}
			Residual Drawdown		66,304	---
		P-2 Lower Core & Pilot	Distance - Drawdown Drawdown vs. Radius	Pumping	69,339 74,500	1.68×10^{-4}
P-3 Test		P-3 Pump	Time - Drawdown (Theis)	Pumping	58	0.105
Q = 3 gpm			Time- Drawdown (Jacob)		61 (early slope) 26 (late slope)	0.085 ---
Duration of Pumping = 30 min.			Residual Drawdown	Recovery	6.7	---

diameter. This would have more accurately reflected true transmissivity and storage coefficient values. Unfortunately, the extremely low production rates at P-2 upper and P-3 precluded the desired high rates of pumping. Calculations indicated that the growth of the drawdown cone would have taken several hundred days to reach the observation well nearest the pump site at P-3. The aquifer at P-2 upper was not encountered anywhere else on the tracts. Despite these limitations certain conclusions may be drawn from the test data:

P-1: The water produced from the P-1 site exceeded 5,000 $\mu mho/cm^2$, and according to the conditions of the AOSO and NPDES permits, the water could not be discharged from the site. Pumping in excess of 3 l/s (45 gpm) was not considered feasible because of the size and integrity of the containment pit at the site. Pumping did continue for a sufficient length of time to provide steady rates of drawdown. The following conclusions were drawn from the test data:

1. The aquifer is under artesian head of about 15 m (50 feet).

2. The drawdown cone did not expand to the observation well nearest the site (884 m, or 2,900 ft).

3. Drawdown and recovery data at the site did not suggest the presence of recharge or discharge boundaries.

4. Data derived are sufficient to indicate a representative transmissivity of about 0.2 l/s/m (1,500 gpd/ft).

P-2 Upper:

1. The P-2 upper aquifer is of limited areal extent and had negligible recharge (based on data plots).

2. Artesian water levels in P-2 lower are below the base of P-2 upper, indicating a potential for downward leakage.

3. Pumping of P-2 lower had no measurable effect on P-2 upper water levels; and correspondingly, pumping of P-2 upper did not result in a measureable response in P-2 lower. In the five months since pumping began, the test water levels have not fully recovered to pre-pumping levels.

4. The representative transmissivity is about 150 gpd/ft.

P-2 lower: The P-2 lower was tested the longest (over six days) at the highest rate of production--35 l/s (500 gpm). The drawdown cone enlarged to a radius of more than 3,354 m (11,000 ft) in about three days, as recorded in observation wells away from the site. Drawdown versus radius indicated that the zero drawdown point was about 12,195 m (40,000 ft) from the pumping well. Water levels had stabilized in the pump and site observation holes. Based on data collected during the test, certain conclusions may be drawn:

1. The artesian head at the site is about 76.2 m (250 ft), which is about 21.3 m (70 ft) below the White River.

2. The creation of only 5.5 m (18± ft) of drawdown in the pumped well after more than six days of continuous pumping of 34.6 l/s (550 gpm) indicates a high transmissivity.

3. Rapid and extensive enlargement of the drawdown cone indicates a high transmissivity.

4. The representative transmissivity of the bird's nest aquifer across most of Tract U-a is about 10.8 l/s/m (75,000 gpd/ft).

5. The significant leveling-off of the declining water level after about three days of pumping may be indicative of--

    a. downward vertical recharge from overlying bedrock aquifers

    b. White River recharge

    c. upward leakage from underlying aquifers, perhaps from the potential Douglas Creek Member

    d. zones of higher transmissivity may have been encountered by the cone of depression

    e. reduced water-table declines caused by water-table conditions to the south and east encountered by the expanding cone.

Based on what is known about the aquifer, the last condition seems the most plausible. Only one bedrock aquifer is known

to exist above the bird's nest (P-2 upper), and it is known to be of limited areal extent. Pumping at the site from either the upper or the lower aquifer (bird's nest) induced no measurable vertical movement of water. The bird's nest static water surface is about 21 m (70 ft) below the river level opposite the P-2 site, so probably there is no interconnection at this location; however, the two are known to be interconnected on Tract U-b about 7.2 km (4.5 mi) up the river, within the projected 12,195-m (40,000-ft) zone of influence. The 50-fold decrease in transmissivity between the P-2 and P-1 sites suggests that the P-2 lower cone could not advance through the low transmissive zone and reach the river during the time of the test. No measurable amounts of water below the bird's nest were encountered to depths of about 122 m (400 ft) below the mahogany marker, indicating that if water is moving upward through the mahogany zone, it does so at exceedingly slow rates. It appears that the water-table conditions to the south and east of the P-2 site were instrumental in causing the drawdown at P-2 lower to stabilize.

P-3:

1. The bird's nest aquifer at this location is 10 percent to 15 percent saturated.

2. The sustained yield is less than 0.2 l/s (3 gpm) (the rate at which the hole was pumped dry).

3. The recovery data indicate that the representative transmissivity is about 15 gpd/ft and that the specific yield is about (0.9).

The calculated artesian storage coefficients in the order of .0001 to .00001 are reasonable values for the solution-fracture type of permeability found in the bird's nest aquifer.

The hydrogeology of the Uinta Basin differs from that of the Piceance Basin, which lies to the east. Although the two are in part contemporaneous, the principal Piceance aquifer is 91.5 m to 152.3 m (300 ft to 500 ft) below the Mahogany Zone in the Douglas Creek Member and is from 91.5 m to 152.3 m (300 ft to 500 ft) thick. Well yields may be as high as 63 l/s (1,000 gpm), and water usually flows at the surface (Coffin et al. 1971).

The Douglas Creek Member was drilled only twice as part of this investigation. Hole G-16A penetrates the member beginning in bedrock about 48.8 m (160 ft) below the mahogany marker and flowing at the ground surface from a depth of

50.3 m (165 ft) SE 1/4 of the SE 1/4 of Section 21, T11S, R25E. Based on records of deep wells some distance away, the well ends in the upper part of the Douglas Creek Member.

c. Ground Water Recharge

The bird's nest aquifer is known to occur within 15.2 m to 38.1 m (50 ft to 125 ft) below the top of the Green River Formation and could follow the outcrop pattern for a great distance around the edges of the Uinta Basin if the aquifer is present everywhere in the formation. It is not known whether this is true beyond 8 km to 9.5 km (5 mi to 6 mi) from the tracts.

Near the junction of U.S. 40 and Utah State Road 45 the aquifer dips steeply along its northern edge at the rate of 189 m/km to 284 m/km (1,000 ft/mi to 1,500 ft/mi). In these areas of steep dip the aquifer is upturned against the ground surface slope (Barlow & Haun, Inc. 1962). Under these conditions, exposures of the aquifer would be excellent for recharge from direct precipitation, snowmelt, and runoff. The results of the field investigations indicate that if the bird's nest aquifer is present in this area, it is covered by the Duchesne River Formation. Conditions are not suited for significant recharge around and south of the tracts because the aquifer dip is not known to exceed 57 m/km (300 ft/mi) and because the aquifer is usually exposed above canyon floors on nearly vertical walls.

Where the aquifer is in contact with alluvium--in the bottom of Evacuation and Bitter creeks, Asphalt Wash, Hells Hole Canyon, and the White River--the recharge potential is increased. This is best illustrated in portions of Sections 35 and 35, T10S, R24E, and at least as far south as G-19 (Section 14, T11S, R24E), where the aquifer is essentially dry. Beginning in Section 6, T11S, R24E, the aquifer is in contact with the alluvium of Evacuation Creek, and it contains water at all locations from that point northward across the tracts.

No water wells, other than those drilled for this investigation, are known to produce water exclusively from the bird's nest aquifer. Two flowing wells in Asphalt Wash were intended to be sealed through the aquifer, but leakage may be occurring from the bird's nest anyway. It is thought that production from the bird's nest in the vicinity of the tracts is minimal; this and the known discharge areas and minimal water-level fluctuations indicate that the aquifer is under steady state conditions, i.e., discharge equals recharge. Intraformational or interformational leakage is

not expected to be a significant source of recharge to the bird's nest aquifer because the major aquifer zones are too well shielded from one another by extensive layers of shaley material.

d. Ground Water Movement and Fluctuation

Data pertaining to water levels in the bird's nest aquifer are not available from wells of record in the vicinity of the tracts except from those drilled for the baseline data collection program. The other wells of record--deep oil-test and gas-test holes--are not reliable indicators of water levels because the levels are a composite of many aquifers. Because data for the water level north of the tract boundaries are not available, it can only be speculated that recharge water migrates from the northern outcrop area and around the rim of the basin to the east to be discharged at points along Evacuation Creek and the White River.

The water-level contours probably conform to the shape of the west-dipping structural contours throughout most of the reach between the U.S. 40 - Utah 45 junction and the tracts. As the contours approach the area of the confluence of Evacuation Creek and the White River, which acts as a pressure sink, the contours probably drop sharply downstream and after crossing the stream, probably bow sharply upstream, enter the tracts, and generally reconform to the regional structural trends. This theory is supported by the disposition of the site-specific water surface contours (Figure II-57). It is also noted that water levels slope toward the west as much as 83.3 m/km (175 ft/mi) across Tract U-b but are at about the same elevation over most of Tract U-a. This is a further indication that the transmissivity at the P-2 site is much higher than that of the P-1 site.

Water levels were continuously recorded at the P- sites from December 1974 through mid-January 1976, as seen on figures II-58 through 61. The water levels of the other wells drilled as part of the baseline program are measured at least monthly, as seen on Figure II-62.

Some of the wells, depending on their location in the body of the aquifer, show that aquifer recharge began in late February 1975 or early March 1975 and declined in early June (e.g., G-10, G-11, G-12, G-14, shown on Figure II-57). These wells are in an area of the bird's nest aquifer that receives recharge from Evacuation Creek or that is exposed at the ground surface and is subject to direct recharge from precipitation (e.g., G-12). Water levels in wells away from the

LEGEND

—5000— CONTOURS ON THE GROUND WATER SURFACE (INTERVAL-50 FEET)

100.0' DEPTH TO WATER

5100 DATE

ELEVATION OF WATER IN FEET ABOVE MEAN SEA LEVEL

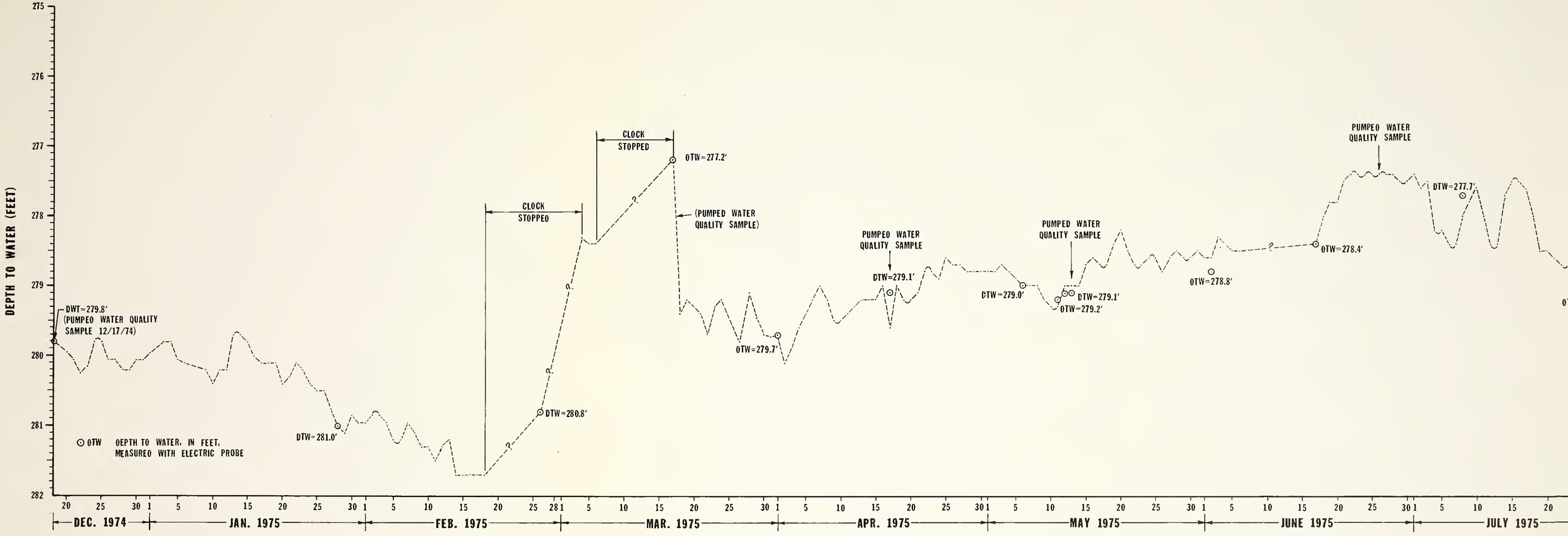
- ⊙ S — SURFACE WATER MONITORING STATION
- ⊙ P — PILOT TEST HOLE (WATER)
- ⊙ G — GROUND WATER MONITORING STATION
- ⊙ HE — EXISTING GEOLOGIC CORE HOLE, EVACUATION
- ⊙ HS — EXISTING GEOLOGIC CORE HOLE, SOUTHAM
- ⊙ X — EXPLORATION GEOLOGIC CORE HOLE
- ⊙ AG — ALLUVIAL WELL (WATER)
- △ AR — PRECIPITATION, AUTO (WATER)
- ▲ RS — PRECIPITATION, STORAGE (WATER)
- × EVP — EVAPORATION PAN (WATER)

1 0 1

SCALE IN MILES

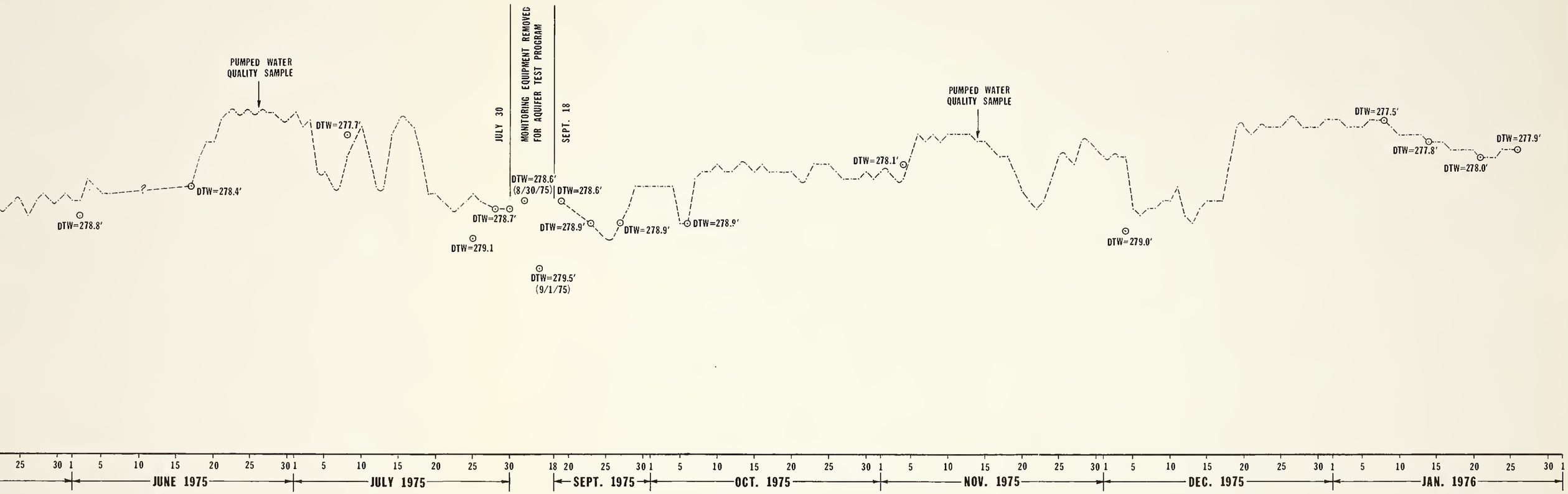
CONTOURS ON THE GROUND WATER SURFACE OF THE BIRDS NEST AQUIFER, MARCH, 1975

FIGURE II-57



CONTINUOUS MONITORING WELL P-1

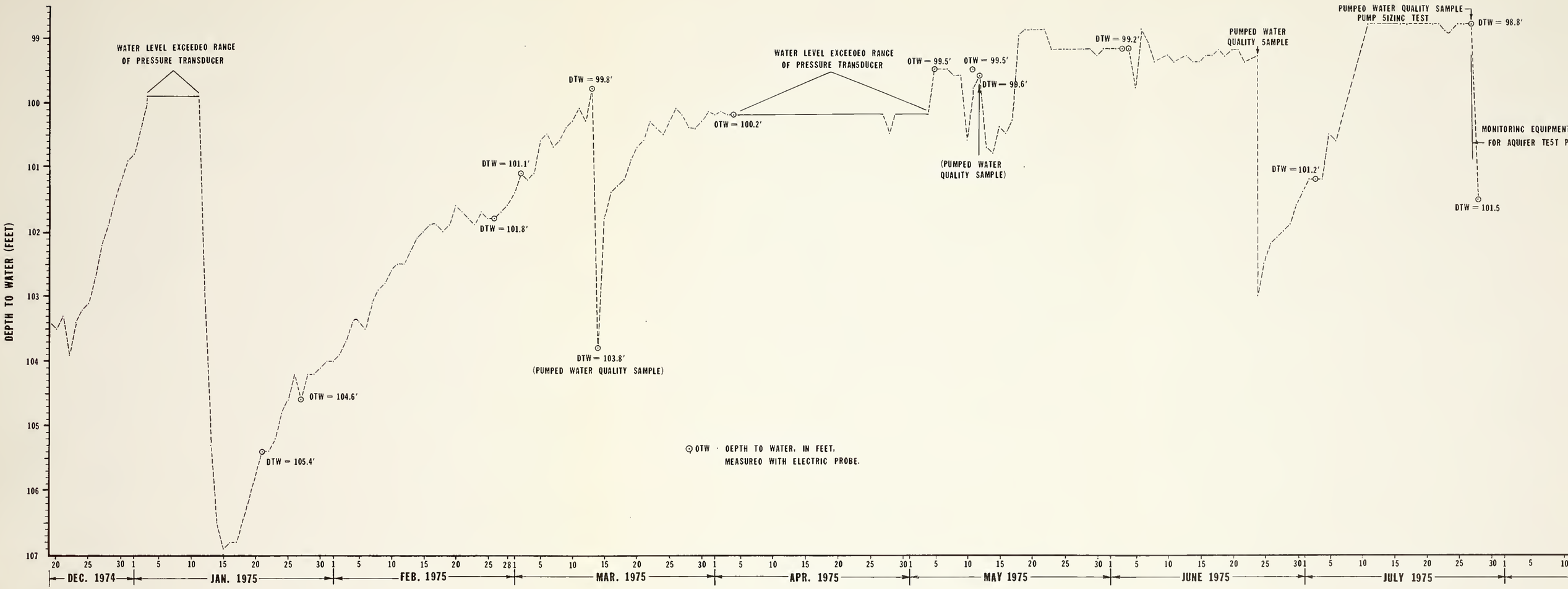
(SURFACE ELEVATION 5284.0')



CONTINUOUS MONITORING WELL P-1

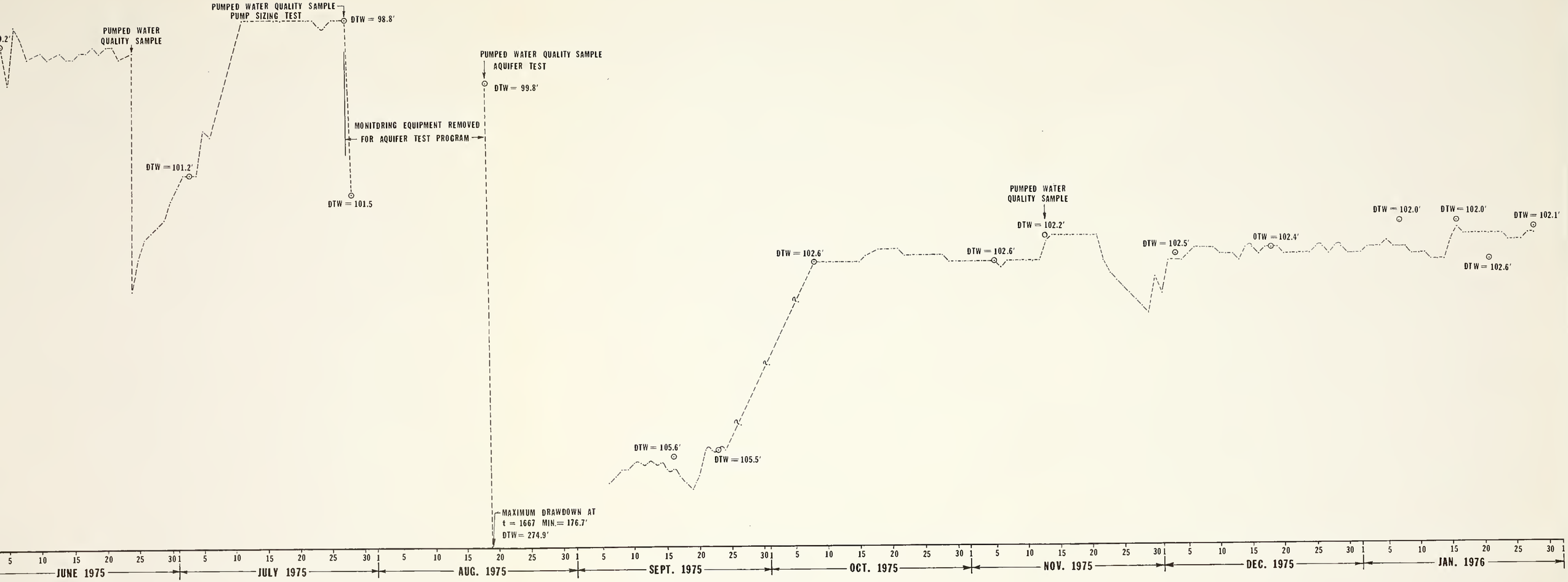
(SURFACE ELEVATION 5284.0′)

FIGURE II-58



CONTINUOUS MONITORING WELL P-2 UPPER

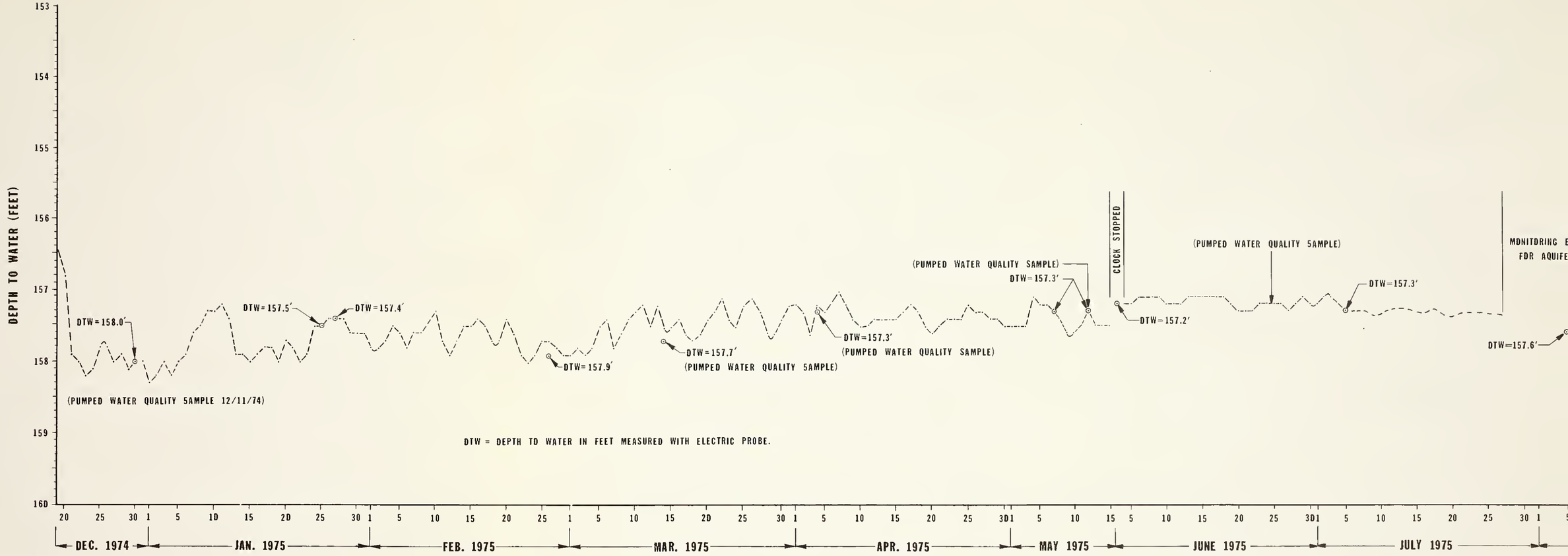
(SURFACE ELEVATION 4991.0')



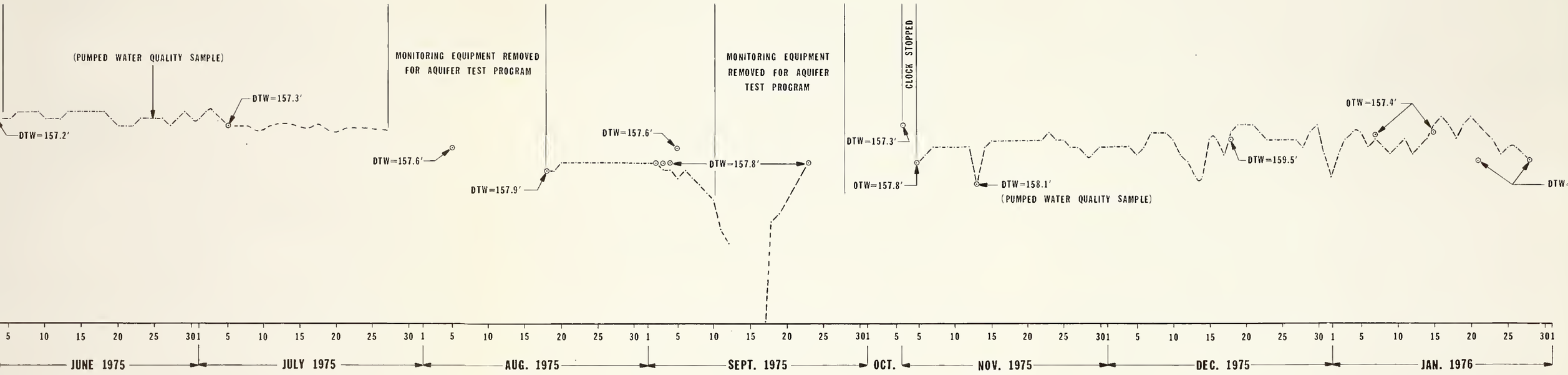
CONTINUOUS MONITORING WELL P-2 UPPER

(SURFACE ELEVATION 4991.0')

FIGURE II-59

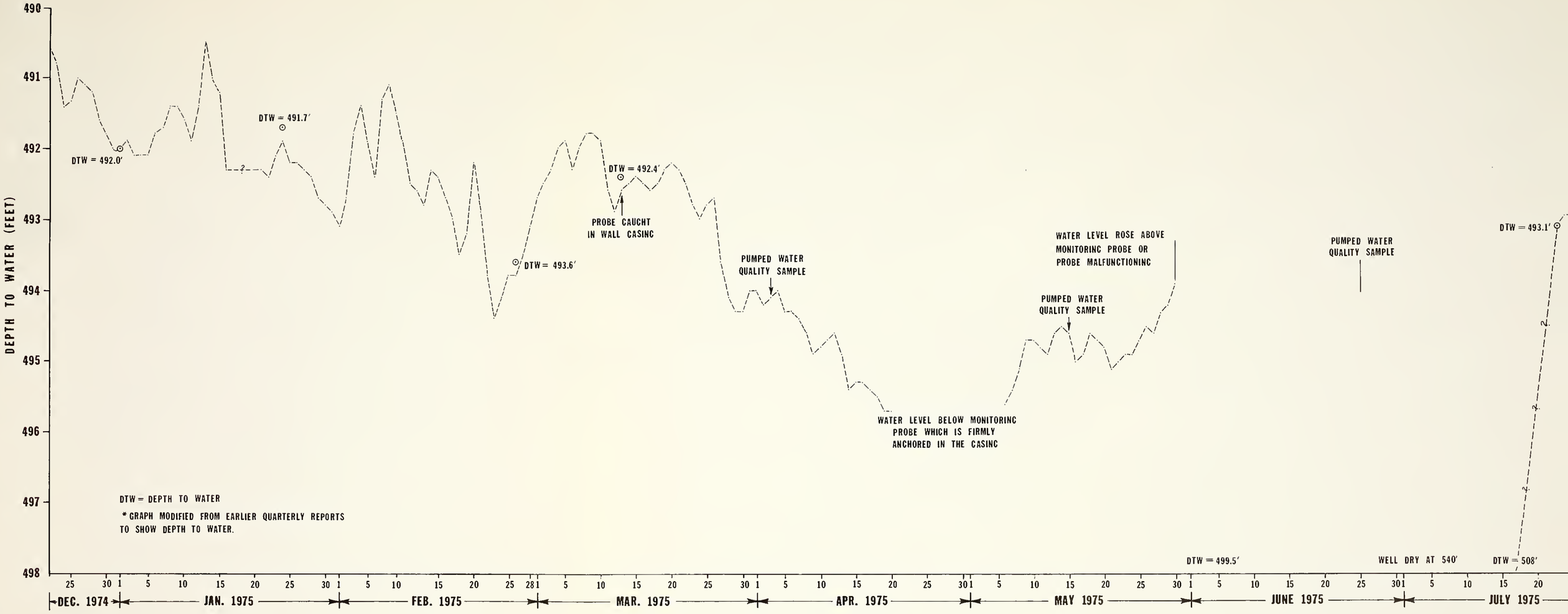


CONTINUOUS MONITORING WELL
P-2 LOWER
(SURFACE ELEVATION = 4991.0 FT.)



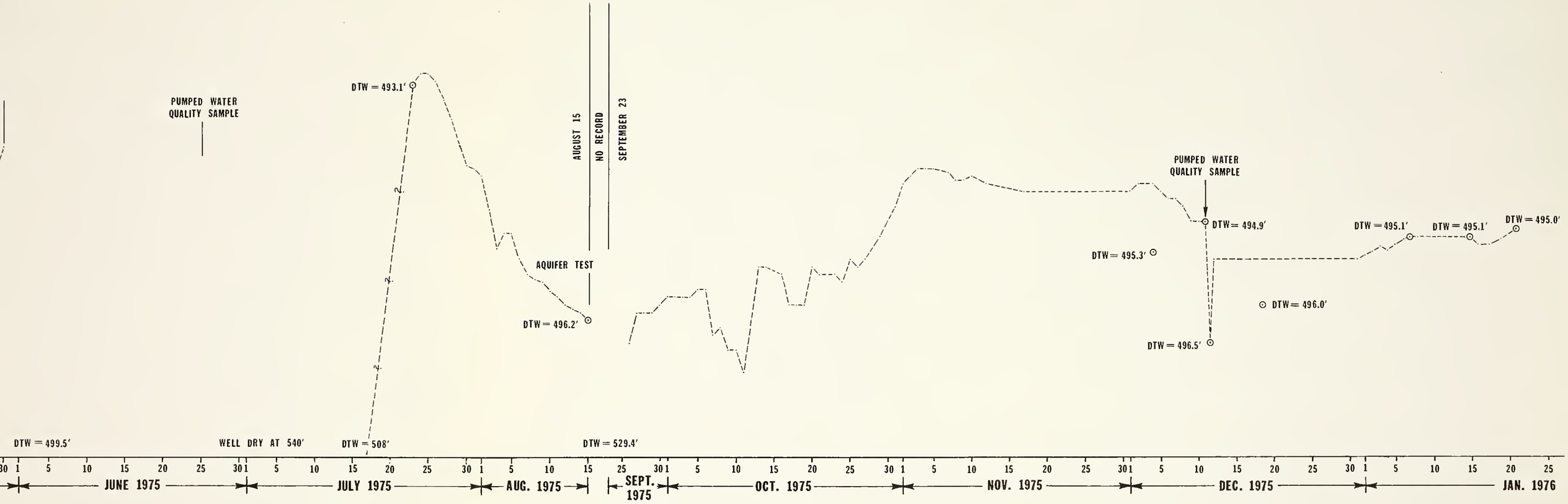
CONTINUOUS MONITORING WELL
P-2 LOWER
(SURFACE ELEVATION = 4991.0 FT.)

FIGURE II-60


DEPTH TO WATER (FEET)
490
491
492
493
494
495
496
497
498
DTW = 492.0′
DTW = 491.7′
DTW = 493.6′
DTW = 492.4′
PROBE CAUGHT IN WALL CASING
PUMPED WATER QUALITY SAMPLE
WATER LEVEL BELOW MONITORING PROBE WHICH IS FIRMLY ANCHORED IN THE CASING
WATER LEVEL ROSE ABOVE MONITORING PROBE OR PROBE MALFUNCTIONING
PUMPED WATER QUALITY SAMPLE
PUMPED WATER QUALITY SAMPLE
DTW = 493.1′
DTW = 499.5′
WELL DRY AT 540′
DTW = 508′
DTW = DEPTH TO WATER
* GRAPH MODIFIED FROM EARLIER QUARTERLY REPORTS TO SHOW DEPTH TO WATER.
25 30 1 5 10 15 20 25 30 1 5 10 15 20 25 28 1 5 10 15 20 25 30 1 5 10 15 20 25 30 1 5 10 15 20 25 30 1 5 10 15 20 25 30 1 5 10 15 20
DEC. 1974
JAN. 1975
FEB. 1975
MAR. 1975
APR. 1975
MAY 1975
JUNE 1975
JULY 1975

CONTINUOUS MONITORING WELL G-7*

(SURFACE ELEVATION = 5486′)



CONTINUOUS MONITORING WELL G-7*

(SURFACE ELEVATION = 5486′)

FIGURE II-61

1974 1975 1976 1977

OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB.

WELL: G-1
T.D. 201.8'
195
200
205

WELL: G-1A
T.D. 37.1'
(ALLUVIAL WELL)
30
35
40

WELL: G-2
T.D. 136.0'
125
130
135

WELL: G-2A
T.D. 39.6'
(ALLUVIAL WELL)
30
35
40

WELL: G-3
T.D. 200.0'
190
195
200

WELL: G-4
T.D. 132.2'
125
130
135

WELL: G-4A
T.D. 18.8'
(ALLUVIAL WELL)
15
20
25

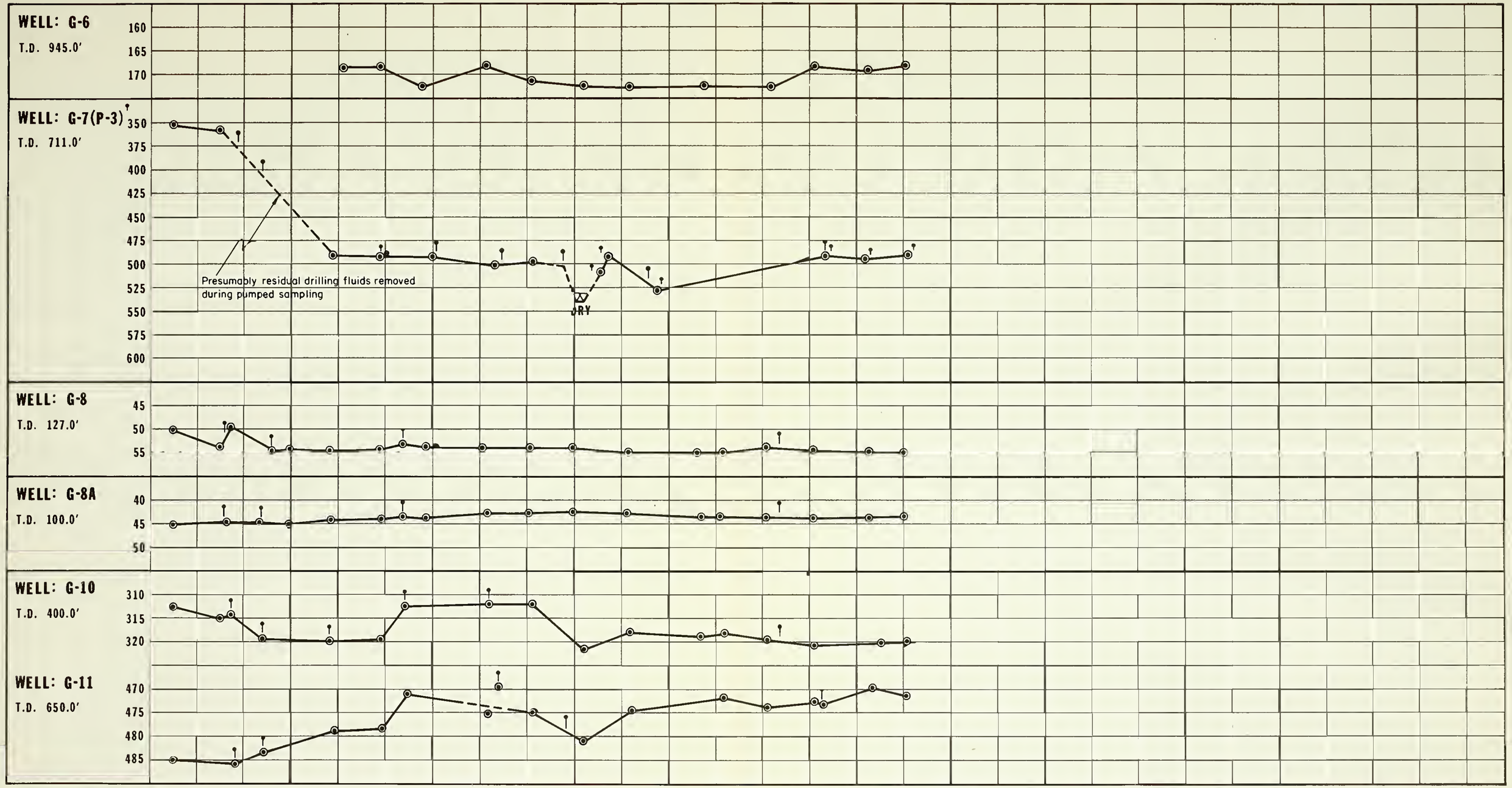
WELL: G-5
T.D. 620.0'
450
455
460
465

▽ – MEASUREMENTS IN DRY HOLE ! – PUMPED OR THIEVED WATER QUALITY SAMPLE ◉ – WATER SURFACE MEASUREMENTS

MONTHLY MEASURED STATIC WATER LEVELS IN WELLS OCT. 1974 - FEB. 1976

WHITE RIVER SHALE PROJECT TRACTS Ua & Ub

FIGURE II-62

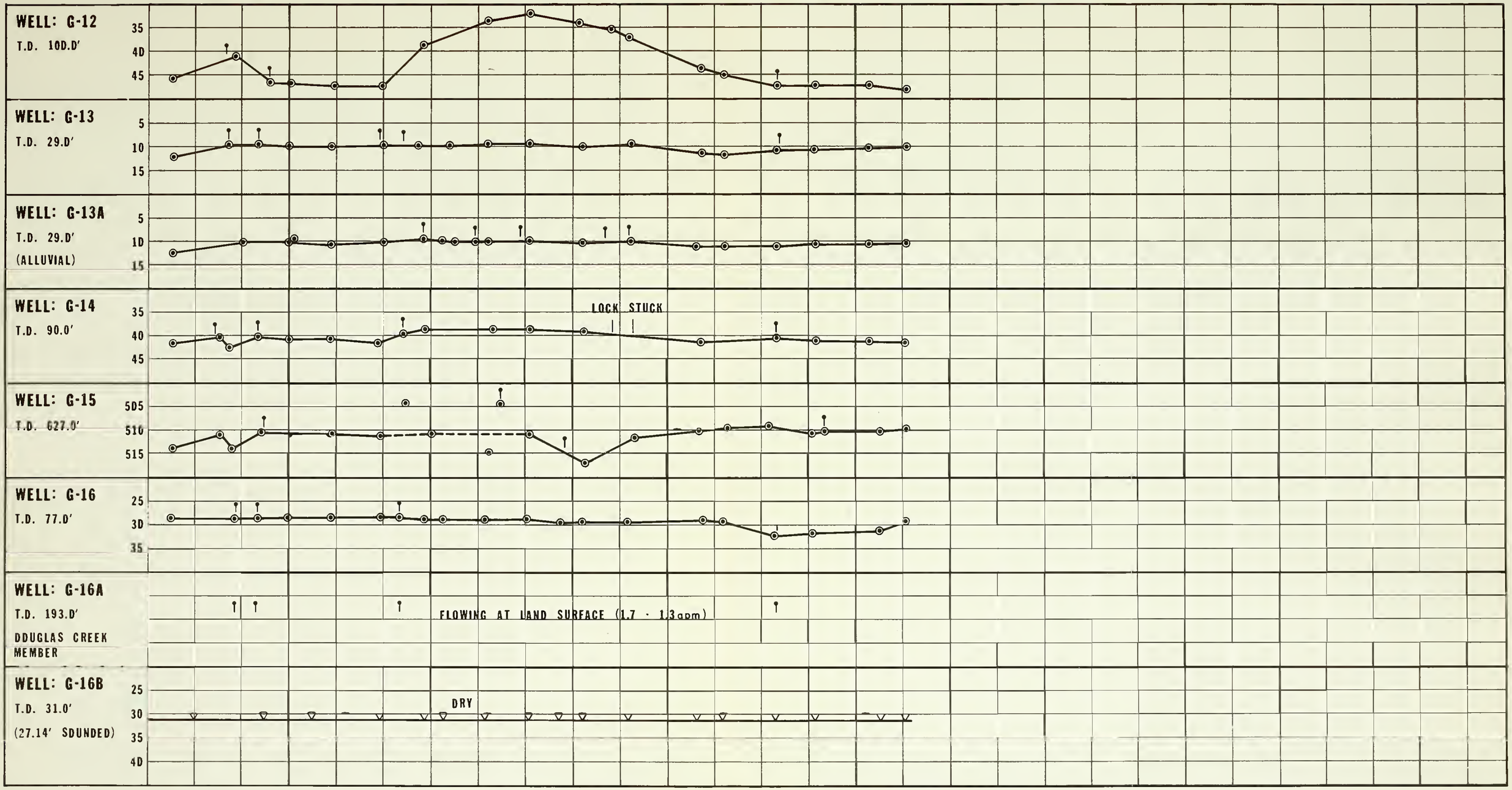


▽ – MEASUREMENTS IN DRY HOLE ⍑ – PUMPED OR THIEVED WATER QUALITY SAMPLE ◉ – WATER SURFACE MEASUREMENTS

MONTHLY MEASURED STATIC WATER LEVELS IN WELLS OCT. 1974 - FEB. 1976

WHITE RIVER SHALE PROJECT TRACTS Ua & Ub

FIGURE II-62 (CON'T)

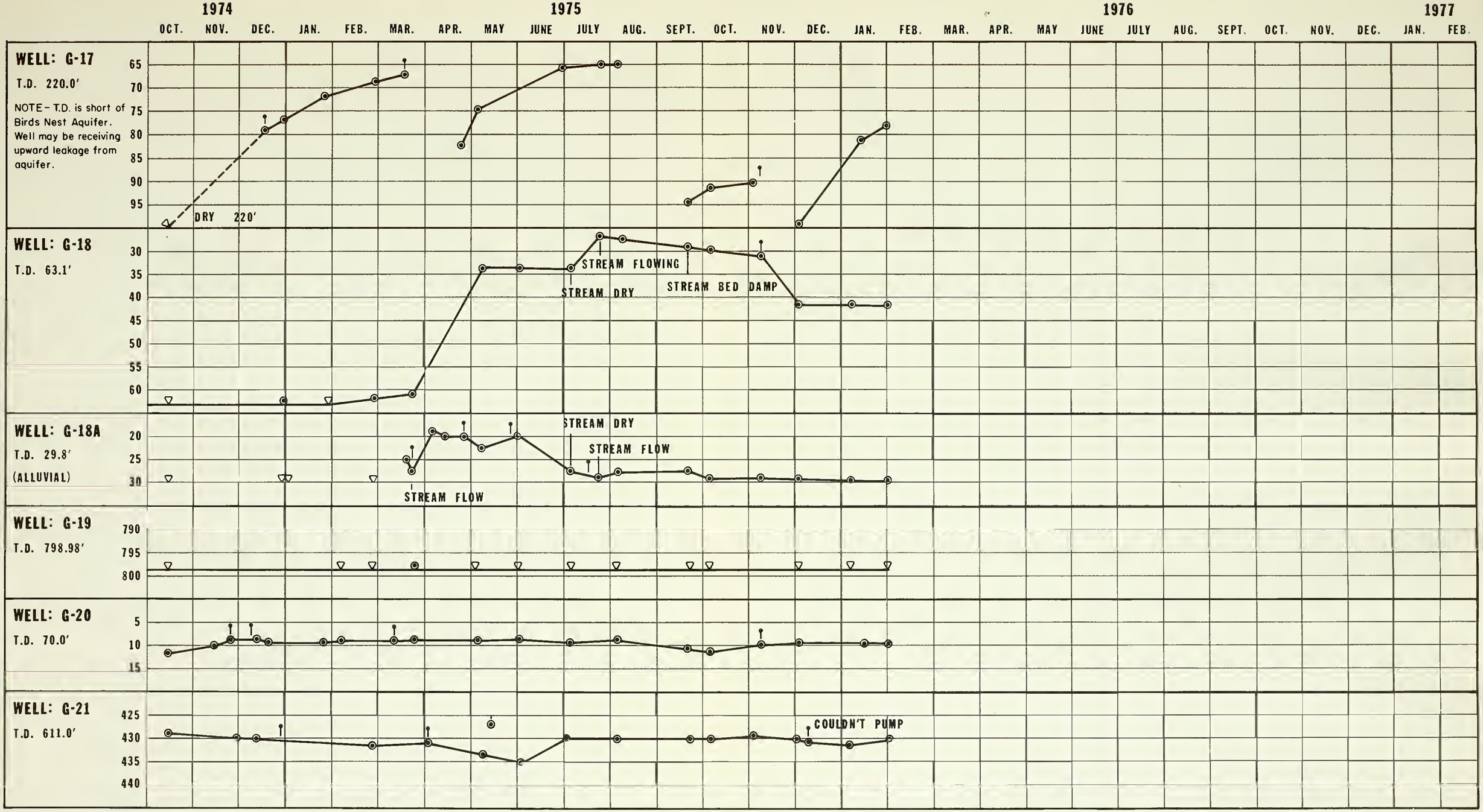


▽ – MEASUREMENTS IN DRY HDLE ⍑ – PUMPED DR THIEVED WATER QUALITY SAMPLE ◉ – WATER SURFACE MEASUREMENTS

MONTHLY MEASURED STATIC WATER LEVELS IN WELLS OCT. 1974 - FEB. 1976

WHITE RIVER SHALE PROJECT TRACTS Ua & Ub

FIGURE II-62 (CON'T)

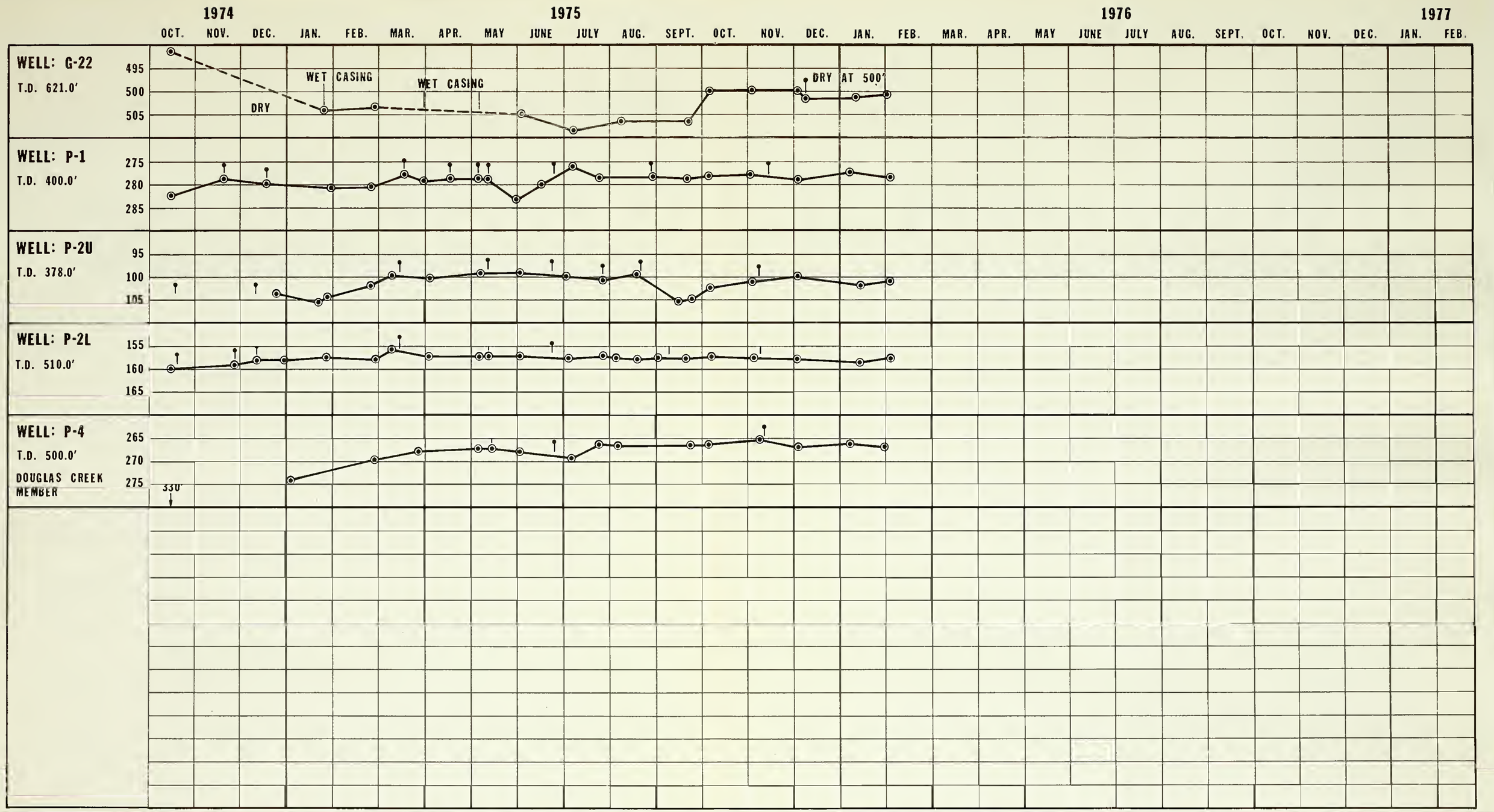


▽ – MEASUREMENTS IN DRY HOLE ↟ – PUMPED OR THIEVED WATER QUALITY SAMPLE ◉ – WATER SURFACE MEASUREMENTS

MONTHLY MEASURED STATIC WATER LEVELS IN WELLS OCT. 1974 - FEB. 1976

WHITE RIVER SHALE PROJECT TRACTS Ua & Ub

FIGURE II-62 (CON'T)



▽ – MEASUREMENTS IN DRY HOLE ↑ – PUMPED OR THIEVED WATER QUALITY SAMPLE ◉ – WATER SURFACE MEASUREMENTS

MONTHLY MEASURED STATIC WATER LEVELS IN WELLS OCT. 1974 - FEB. 1976

WHITE RIVER SHALE PROJECT TRACTS Ua & Ub

FIGURE II-62 (CON'T)

outcropping edges of the aquifer show no such response to recharge, indicating that the main body of the reservoir is full to capacity.

e. Ground Water Discharge

Discharge from the aquifer in the form of seeps and springs is common along the down-dip portions of the aquifer on the east walls of Hells Hole and Evacuation Creek canyons. The same is true of the large patch of isolated aquifer in the northeast portions of T11S,R25E (see Section V.B.3.c, Figure V-11). This water is lost to the main body of the aquifer before it can continue its westward migration into the central part of the basin.

The aquifer is apparently under equilibrium conditions, because discharge equals recharge. The main body of the aquifer is full to capacity, as indicated by the springs and seeps on the west side of Evacuation Creek beginning about 1.6 km (1 mi) south of the southern boundary of Tract U-b and continuing intermittently to the confluence of the White River. Seepage is especially prevalent in the west center of Section 13, T10S,R24E, where a flow of relatively consistent quality and quantity is provided to the S-2 stream gaging site. The aquifer is also in contact with the White River at an elevation of about 1,523 m (5,000 ft) in the NE 1/4 of the NE 1/4 of Section 12, T10S,R24E, and is discharging to the river at this location, as evidenced by the presence of seeps along the wall of the canyon.

Under baseflow conditions, the surface water station (S-2 near the Utah-45 bridge and Evacuation Creek) recorded flows of 28.3 l/s to 42.4 l/s (1.0 cfs to 1.5 cfs) during the last water year. This flow is believed to be ground water effluent from the bird's nest aquifer, which crops out in the streambed at that location. If this rate is assumed to be more or less constant over the past water year, as much as $1.11 \times 10^6 m^3$ (900 acre-ft) of ground water effluent may have passed the S-2 gage in the water year ending October 31, 1975. The aquifer continues to discharge into the stream for several hundred meters downstream of the surface water station, and actual ground water rates of effluent may be much larger. There is no available estimate of discharge from the aquifer outcrop in the White River on Tract U-b.

No other points of discharge from the main body of the reservoir have been observed within the area of investigation. Bitter Creek and the Green River may be additional discharge points in T10S, R19E, but Price and Miller (1974) did not inventory any springs there. Price and Miller (1974) suggest

that ground water accretion to stream flow in the southern Uinta Basin area (bounded by the Duchesne, White, and Strawberry rivers) is approximately 3.7×10^7 m^3 (30,000 acre-feet) per year. Price and Miller (1974) estimated the combined ground water production from wells in the southern Uinta Basin to be about 6.17×10^5 m^3 (500 acre-feet) per year.

f. Ground Water Storage and Change in Storage

Ground water in storage includes the saturated portion of the aquifer and any volume of water under artesian pressure. The ground water storage estimates for the tracts are summarized on Table II-17.

As previously noted, data and observations of the bird's nest aquifer indicate that as the water level rises, the discharge into Evacuation Creek (and presumably into the White River) increases. Thus, in its current unstressed state, the level of the water surface in the aquifer is controlled more by the elevation of the discharge points than by the amount of recharge. Because of these conditions, and as the available record indicates, it is assumed that the long-term change in storage is zero. The records available for the period of January 15, 1975, through January 15, 1976, indicate that the average net change of water levels in all wells monitored in the bird's nest aquifer was approximately +0.3 m (1.0 ft), including both artesian and water table responses.

g. Ground Water Quality

Austin and Skogerboe (1970) included a comprehensive discussion of ground water quality throughout the Uinta Basin. Table II-18 summarizes the ground water data available in that report and describes waters of the Mesa Verde, Wasatch, Green River, and Uinta Formations in terms of total dissolved solids (TDS). According to the available data, the Green River Formation consistently contains the lowest TDS content of all the formations. As shown in Figure II-63, the water quality is best near the periphery of the basin and gradually deteriorates toward the central part of the basin.

Feltis (1968) suggested that as indicated by good water quality resulting from rainfall and snowmelt recharge, the main area of aquifer recharge was along the northern and northwestern part of the basin. Not all the aquifers discussed by Feltis crop out in these areas and therefore, are

TABLE II-17

GROUND WATER IN STORAGE IN THE BIRD'S NEST AQUIFER
TRACTS U-a AND U-b UINTA COUNTY, UTAH

Saturated thickness* meters (feet)		Area** hectares (acres)		Ground Water in Storage*** $10^6 m^3$ (acre-ft)	
+107	(+350) [probably 114 m (375 ft)]	238.5	(588.8)	7.27	(5,890)
+99	(+325)	194.4	(480.0)	5.92	(4,802)
+84	(+275)	285.1	(704.0)	8.69	(7,042)
+69	(+225)	409.5	(1,011.2)	12.48	(10,114)
+53	(+175)	819.1	(2,022.4)	24.95	(20,226)
+38	(+125)	681.7	(1,683.2)	20.76	(16,833)
23	(75)	629.9	(1,555.2)	14.39	(11,664)
8	(25)	518.4	(1,280.0)	3.95	(3,200)
0	0	365.5	(902.4)	0	0
	Total	4142.0	(10,227.2)	98.40	(79,771)

*If the value of thickness is preceded by a +, it includes artesian head and 30 meters (100 ft) of saturated thickness. If the value is less than 30 m, it represents the actual saturated thickness under water table conditions.

**Area determined by planimetry between contours on tract as shown on Figure II-56 (Sect. II.C.2.a).

***For artesian head conditions, a storage coefficient of 1.8×10^{-5} was used; for the saturated aquifer, a specific yield value of 0.1 was used.

TABLE II-18

GROUNDWATER QUALITY DATA
IN THE UINTA BASIN, UTAH

Formation	Location (T/R)	Source	Yield (GPM)	Total Dissolved Solids (ppm)
Mesa Verde	9S/23E	-	-	12,511 - 62,502
	10S/24E (2)	Oil Well	1	
	12S/14E	Oil Well	-	
	17S/17E	Spring	-	707
	20S/20E (2)	Oil Well	-	660 - 1,090
Wasatch Formation	15S/21E	-		1,966
	1N/1E (USM)	-		1,302
	16S/17E	Spring	225 (Sept. 1948)	596
Green River Formation	11S/12E	Gas Well	0.5 - 220 gpm	619
	14S/20E	Oil Well		818
	15S/23E	Spring		381
	2N/2W (USM)	Oil Well		348 (from 4,115 ft)
	10S/20E-35	Gas Well	80 (flow)	-
	10S/22E-17	Gas Well	10 (flow)	-
	*9S/24E	Oil Well	220	- (from 1,932 ft)
Uinta Formation	7S/22E	Oil Well	-	2,365
	7S/24E	Oil Well	110	898
	9S/23E	Oil Well	30	81,200
	4S/5W (USM)	Oil Well	30	22,915
	1S/8W (USM)	Spring	50	237
	4S/7W (USM)	Spring	20	7,320
	5S/6W (USM)	Spring	200	1,840
	5S/7W (USM)	Spring	225	2,710
	2S/5W (USM)	Water Well	-	439
	3S/3W (USM)	Water Well	20	788
	3S/8W (USM)	Water Well	-	4,430

*Largest reported yield from the Green River formation in the Uinta Basin (Austin & Skogerboe, 1970).

LEGEND

Tdr	DUCHESNE RIVER FORMATION
Tu	UINTA FORMATION
Tgr	GREEN RIVER FORMATION - UNDIVIDED
Tgp	GREEN RIVER FORMATION - PARACHUTE CREEK MEMBER
Tgd	GREEN RIVER FORMATION - DOUGLAS CREEK MEMBER
○	WATER WELL
⊙	OIL, GAS, OR TEST WELL
⚲	SPRING

DISSOLVED SOLIDS

SODIUM (Na)+ POTASSIUM (K)
CALCIUM (Ca)
MAGNESIUM

826

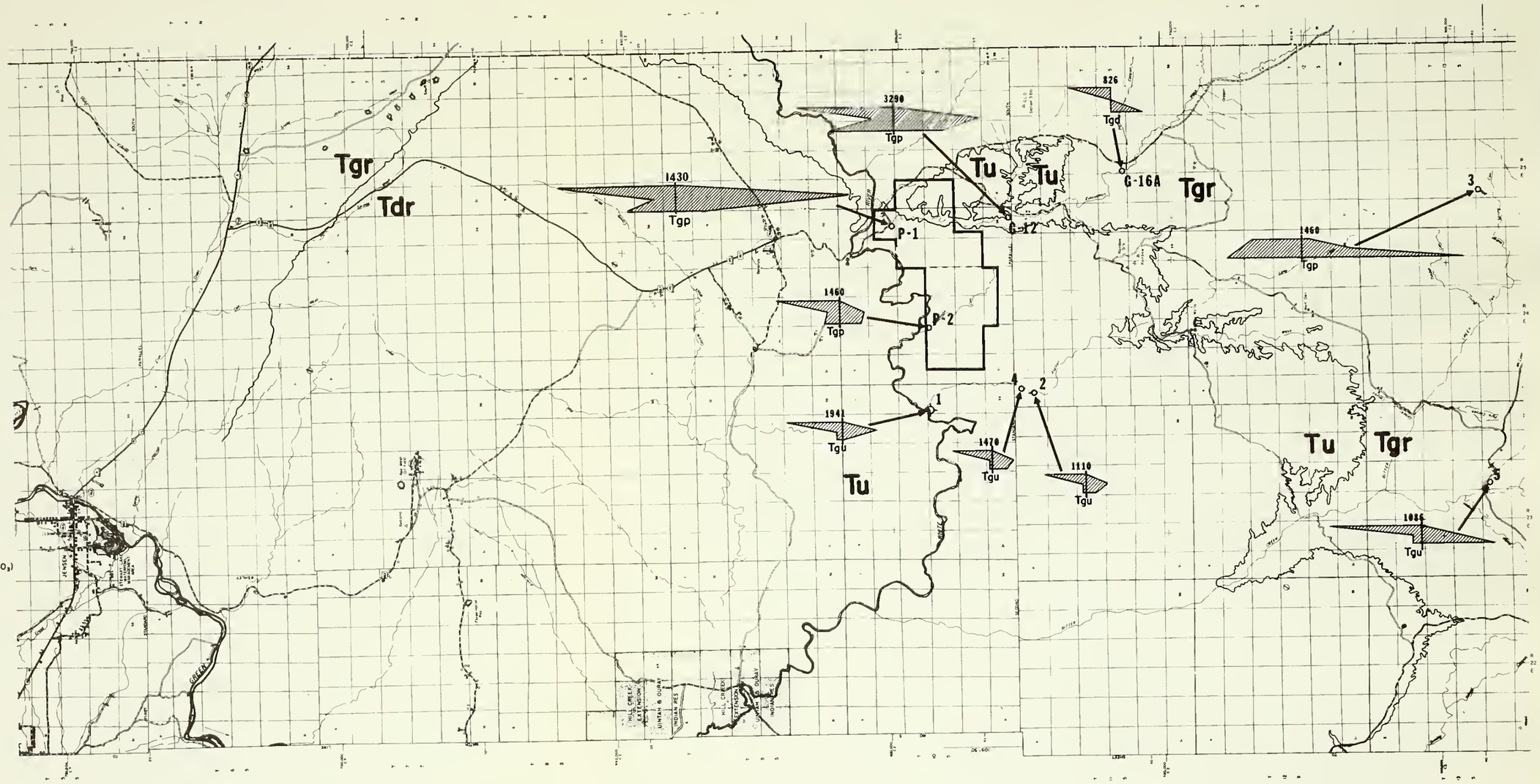
CHLORIDE (Cl)
SULFATE (SO_4)
BICARBONATE (HCO_3)

5 0 5
20 0 20
MILLIEQUIVALENTS PER LITER
(compressed scale for shaded diagrams)

UTAH

N

2 1 0 2
SCALE IN MILES



STIFF DIAGRAMS OF REGIONAL GROUND WATER QUALITY

FIGURE II-63

not subject to direct recharge. According to Feltis, these areas of high quality water are a result of interformational leakage. Electric well log data indicate that throughout the regional area of investigation the water-bearing zones of the Mesa Verde, Wasatch, and Green River Formations appear to be well isolated from one another by shales. The subsurface extent of fracturing is not known, but surface fracture patterns are continuous through the upper Green River and Uinta Formations. If fracturing is continuous into the lower formations, hydraulic communication is possible.

Ground water in the regional area varies in boron content, sodium absorption ratio (SAR), and salinity hazard. The available data (Price and Miller) following values apply for the immediate vicinity of the tracts.

Location	*Sodium Absorption Ratio	*Salinity Hazard (micromhos/cm)	Boron (mg/l)
10S/21E-16	99 (very high)	3,080 (very high)	--
11S/24E-08	49 (very high)	1,820 (high)	--
11S/21E-31	75 (very high)	1,490 (high)	.29
11S/24E-06	60 (very high)	1,800 (high)	--

*Based upon irrigation water classification of the U.S. Salinity Laboratory Staff, 1954

According to these data the ground water is poor to marginal for most uses. In general, the best water is that of the Book Cliffs area south of the tracts.

Much ground water quality information has been obtained as part of the baseline data collection program, and a comprehensive list of constituents was determined for each sample (Tables II-19 through 23). The ground waters for which chemical quality is available are those from the bird's nest aquifer, the Douglas Creek Member, and the alluvium of Evacuation Creek. The bird's nest aquifer contains water of two qualities, both differing in TDS concentrations. The qualities differ along a diagonal line, or zone, from the vicinity of Well P-3 on Tract U-b northwest to Tract U-a on the east side of Well G-5 (Figure II-64). Possible explanations for this are as follows:

1. There may be a retardant to ground water in this area.

TABLE II-19

SUMMARY OF GROUND WATER QUALITY
ALLUVIAL AQUIFER
March 24, 1975 thru August 6, 1975
G-13A, G-18A

Description	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	7	12.9	8.8	32.2	7.3
Conductance (µmhos)	9	5189.	1237.	8000.	3700.
Chemical Oxygen Demand (mg/l)	9	87.	50.	180.	34.
pH (pH Units) 1/	4	9.9	2.0	12.4	7.9
Carbon Dioxide (mg/l)	4	1.8	2.9	1.1	0.0
Alkalinity (mg/l $CaCO_3$)	9	569.	457.	1530.	66.
Bicarbonate (mg/l HCO_3)	9	377.	383.	1160.	0
Carbonate (mg/l CO_3)	8	13.	16.	38.	0
Filterable Residue (mg/l)	5	4120.	988.	5000.	3000.
Oil & Grease (mg/l)	8	2.	1.	3.	1.
Ammonia (mg/l N)*	9	0.18	1.17	0.50	0.03
Nitrite (mg/l N)*	9	0.27	0.32	0.77	0.00
Nitrate (mg/l N)*	9	0.37	0.45	1.50	0.00
Kjeldahl Nitrogen (mg/l N)	9	1.52	0.8	3.4	0.62
NO_2 + NO_3 (mg/l N)*	9	0.64	0.59	1.80	0.00
Orthophosphate (mg/l PO_4)*	9	0.05	0.05	0.12	0.00
Phosphorous (mg/l)	9	0.21	0.34	1.1	0.00
Orthophosphorous (mg/l P)*	9	0.02	0.02	0.04	0.00
Total Organic Carbon (mg/l)	9	31.	15.	60.	13.
Total Inorganic Carbon (mg/l)	2	447.	439.	757.	136.
Sulfide (mg/l)	8	0.0	0.1	0.2	0.0
Hardness (mg/l Ca, Mg)	9	1023.	310.	1500.	530.
Non Carbonate Hardness (mg/l)	9	747.	395.	1400.	0.
Calcium (mg/l)*	9	266.	143.	580.	130.
Magnesium (mg/l)*	9	86.	92.	200.	0.2
Sodium (mg/l)*	9	756.	133.	930.	550.
Sodium Adsorption Ratio	9	11.	2.	14.	6.3
% Sodium	9	39.	28.	75.	4.5
Potassium (mg/l)*	9	14.	6.	25.	6.4
Chloride (mg/l)*	9	51.	8.	63.	44.
Sulfate (mg/l)*	9	1967.	695.	2800.	1000.
Fluoride (mg/l)*	9	0.6	0.3	1.0	0.2
Silica (mg/l)*	9	5.0	3.8	9.3	0.7
Arsenic (mg/l)*	9	0.001	0.001	0.001	0.000
Barium (mg/l)*	6	<0.033	0.052	<100	0.000
Beryllium (mg/l)*	6	<5.	5.	<10.	0.000
Boron (mg/l)*	9	0.840	0.820	2.000	0.040
Cadmium (mg/l)*	8	0.000	0.000	0.000	0.000
Chromium (mg/l)*	6	0.005	0.008	0.020	0.000
Cobalt (mg/l)*	8	0.0002	0.0007	0.002	0.000
Copper (mg/l)*	7	0.053	0.039	0.130	0.012
Iron (mg/l)*	8	0.031	0.023	0.070	0.010
Lead (mg/l)*	8	0.004	0.005	0.014	0.000
Manganese (mg/l)*	7	0.025	0.029	0.070	0.000
Mercury (mg/l)*	8	0.00001	0.00004	0.00010	0.00000
Molybdenum (mg/l)*	6	0.098	0.084	0.250	0.041
Nickel (mg/l)*	8	0.004	0.002	0.007	0.000
Silver (mg/l)*	8	0.000	0.000	0.000	0.000
Strontium (mg/l)*	6	2.483	0.591	3.300	1.800
Vanadium (mg/l)*	9	0.0012	0.0014	0.0041	0.0000
Zinc (mg/l)*	7	0.020	0.014	0.040	0.010
Aluminum (mg/l)*	6	0.032	0.012	0.050	0.020
Lithium (mg/l)*	8	0.112	0.015	0.130	0.090
Selenium (mg/l)*	6	0.003	0.001	0.004	0.002
Gross Beta (pc/l, Cs-137)*	5	41.	29.	92.	24.
Dissolved Solids (mg/l)*	9	3429.	698.	4310.	2740.
Gross Alpha (mg/l U)*	5	<0.108	0.130	0.340	<0.033
Gross Beta (pc/l SR_{90}/Y_{90})	5	0.034	0.025	0.078	0.019

* Elements analyzed only for dissolved fraction

1/ Arithmetic determination

TABLE II-20

SUMMARY OF GROUND WATER QUALITY
BIRDS NEST AQUIFER (NE)
November 19, 1974 thru November 14, 1975
G-8, G-8A, G-10, G-11, G-12, G-14, G-22, P-1

Description	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	30	12.9	2.4	19	10
Conductance (µmhos)	34	4459.	1208.	6070.	1130.
Chemical Oxygen Demand (mg/l)	32	91.	139.	760.	4.
pH (pH Units)[1/]	26	7.6	0.2	8.1	7.2
Carbon Dioxide (mg/l)	23	29.	17.	81.	6.8
Alkalinity (mg/l $CACO_3$)	31	541.	245.	1650.	216.
Bicarbonate (mg/l HCO_3)	31	643.	319.	2010.	26.
Carbonate (mg/l CO_3)	30	4.2	21.	117.	0.
Filterable Residue (mg/l)	25	3994.	1386.	5200.	590.
Oil & Grease (mg/l)	31	3.0	4.1	21.	0.
Ammonia (mg/l N)*	31	1.2	2.7	15.	0.00
Nitrite (mg/l N)*	31	0.04	0.12	0.65	0.00
Nitrate (mg/l N)*	27	1.70	6.3	30.	0.00
Kjeldahl Nitrogen (mg/l N)	32	2.2	3.9	22.	0.05
NO_2 + NO_3 (mg/l N)*	32	1.8	6.1	30.	0.00
Orthophosphate (mg/l PO_4)*	30	0.11	0.22	1.2	0.00
Phosphorous (mg/l)	31	0.16	0.36	1.4	0.00
Orthophosphorous (mg/l P)*	32	0.03	0.07	0.40	0.00
Total Organic Carbon (mg/l)	29	27.	41.	230.	2.3
Total Inorganic Carbon (mg/l)	23	64.6	91.5	378.	0.
Sulfide (mg/l)*	31	18.	35.	150.	0.
Hardness (mg/l Ca, Mg)	31	957.	381.	1400.	22.
Non Carbonate Hardness (mg/l)	31	483.	354.	980.	0.
Calcium (mg/l)*	31	131.	64.	210.	5.7
Magnesium (mg/l)*	31	153.	64.	240.	0.
Sodium (mg/l)*	31	807.	293.	1500.	72.
Sodium Adsorption Ratio	31	13.	8.	52.	1.8
% Sodium	31	63.	12.	98.	34.
Potassium (mg/l)*	31	6.8	2.8	13.	2.3
Chloride (mg/l)*	31	70.	22.	140.	36.
Sulfate (mg/l)*	31	2009.	843.	3000.	180.
Fluoride (mg/l)*	31	1.4	1.5	8.4	0.2
Silica (mg/l)*	31	16.	7.	27.	7.4
Arsenic (mg/l)*	31	0.012	0.012	0.050	0.001
Barium (mg/l)*	33	<0.070	0.048	<0.200	0.000
Beryllium (mg/l)*	33	<0.008	0.004	0.200	0.000
Bismuth (mg/l)*	29	<0.028	0.017	<0.075	0.003
Boron (mg/l)*	33	3.43	4.58	16.00	0.03
Cadmium (mg/l)*	33	0.0001	0.0004	0.001	0.000
Chromium (mg/l)*	33	<0.009	0.008	<0.027	0.000
Cobalt (mg/l)*	33	<0.004	0.008	<0.027	0.000
Copper (mg/l)*	33	<0.82	4.34	2.50	0.00
Iron (mg/l)*	33	0.56	0.90	4.70	0.00
Lead (mg/l)*	33	<0.007	0.018	0.100	0.000
Manganese (mg/l)*	33	0.058	0.063	0.230	0.000
Mercury (mg/l)*	31	<0.00004	0.00006	0.0002	0.000
Molybdenum (mg/l)*	33	<0.048	0.067	0.260	0.000
Nickel (mg/l)*	33	<0.011	0.013	0.054	0.000
Silver (mg/l)*	33	<0.0006	0.0010	<0.005	0.000
Strontium (mg/l)*	33	6.75	3.45	13.0	0.22
Vanadium (mg/l)*	33	<0.005	0.007	<0.027	0.000
Zinc (mg/l)*	33	0.054	0.084	0.490	0.010
Tin (mg/l)*	29	<0.029	0.019	<0.080	<0.003
Aluminum (mg/l)*	33	<0.026	0.053	0.290	0.000
Gallium (mg/l)*	29	<0.012	0.008	<0.035	<0.001
Germanium (mg/l)*	29	<0.031	0.019	<0.058	<0.003
Lithium (mg/l)*	33	0.45	0.40	1.40	0.00
Selenium (mg/l)*	31	0.002	0.005	0.022	0.000
Titanium (mg/l)*	29	<0.021	0.012	<0.050	<0.003
Zirconium (mg/l)*	29	<0.043	0.026	<0.100	<0.005
Gross Beta (pc/l Cs-137)*	25	<18.0	9.4	40.0	<6.0
Dissolved Solids (mg/l)*	31	3556.	1210.	5060.	556.
Gross Alpha (mg/l U)*	25	<0.407	0.021	0.085	<0.006
Gross Beta (pc/l SR_{90}/Y_{90})*	25	<14.9	7.5	32.0	<5.3

1/ Arithmetic Determination

* Elements analyzed only for dissolved fraction

TABLE II-21

SUMMARY OF GROUND WATER QUALITY
BIRDS NEST AQUIFER (SW)
October 18, 1974 thru November 13, 1975
G-5, G-15, G-21, P-2L, P-3

Description	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	24	16.4	1.4	19.5	14.0
Conductance (µmhos)	26	2443.	1065.	5000.	300.
Chemical Oxygen Demand (mg/l)	25	138.	99.	370.	8.
pH (pH Units)[1/]	25	9.0	0.9	10.7	7.4
Carbon Dioxide (mg/l)	25	6.4	12.5	61.0	0.0
Alkalinity (mg/l $CACO_3$)	26	867.	462.	2750.	368.
Bicarbonate (mg/l HCO_3)	26	828.	321.	1710.	387.
Carbonate (mg/l CO_3)	26	112.	165.	808.	0.
Filterable Residue (mg/l)	21	1890.	815.	3800.	180.
Oil & Grease (mg/l)	24	3.	2.	9.	0.
Ammonia (mg/l N)*	26	1.43	1.52	8.10	0.43
Nitrite (mg/l N)*	24	0.00	0.01	0.02	0.00
Nitrate (mg/l N)*	24	0.02	0.05	0.24	0.00
Kjeldahl Nitrogen (mg/l N)	26	2.15	2.16	0.58	12.00
NO_2 + NO_3 (mg/l N)*	25	0.02	0.05	0.25	0.00
Orthophosphate (mg/l PO_4)*	25	0.21	0.26	0.98	0.00
Phosphorous (mg/l)	26	0.16	0.20	0.90	0.00
Orthophosphorous (mg/l P)*	25	0.07	0.08	0.32	0.00
Total Organic Carbon (mg/l)	24	14.5	15.1	66.0	1.9
Total Inorganic Carbon (mg/l)	10	82.1	121.4	386.0	0.0
Sulfide (mg/l)*	26	72.8	84.4	340.0	0.1
Hardness (mg/l Ca, Mg)	26	82.	60.	200.	8.
Non Carbonate Hardness (mg/l)	26	0.	0.	0.	0.
Calcium (mg/l)*	26	10.7	14.7	75.0	0.8
Magnesium (mg/l)*	26	12.9	9.8	30.0	1.0
Sodium (mg/l)*	26	619.	281.	1500.	300.
Sodium Adsorption Ratio	26	44.	44.	234.	13.
% Sodium	26	93.	5.	100.	83.
Potassium (mg/l)*	26	2.7	1.5	8.1	1.4
Chloride (mg/l)*	25	150.	176.	330.	31.
Sulfate (mg/l)*	25	388.	227.	1200.	91.
Fluoride (mg/l)*	25	2.1	1.3	5.3	1.0
Silica (mg/l)*	25	15.0	6.1	27.0	3.3
Arsenic (mg/l)*	26	0.036	0.036	0.210	0.001
Barium (mg/l)*	26	<0.117	<0.115	0.500	0.000
Beryllium (mg/l)*	26	<0.006	<0.005	0.020	0.000
Bismuth (mg/l)*	20	<0.016	<0.009	<0.046	<0.007
Boron (mg/l)*	27	3.440	5.178	26.000	0.500
Cadmium (mg/l)*	26	0.00008	0.00027	0.00100	0.00000
Chromium (mg/l)*	26	<0.008	<0.007	0.025	0.000
Cobalt (mg/l)*	26	<0.002	<0.004	<0.011	0.000
Copper (mg/l)*	27	<0.007	<0.011	0.044	0.000
Iron (mg/l)*	27	0.127	0.150	0.730	0.000
Lead (mg/l)*	26	<0.003	<0.003	<0.011	0.000
Manganese (mg/l)*	26	0.027	0.049	0.250	0.000
Mercury (mg/l)*	26	<0.00004	<0.00006	<0.00020	0.00000
Molybdenum (mg/l)*	26	0.015	0.030	0.140	0.000
Nickel (mg/l)*	26	<0.007	<0.009	0.042	0.000
Silver (mg/l)*	26	<0.0003	<0.0005	<0.0020	0.0000
Strontium (mg/l)*	27	1.703	1.326	4.800	0.060
Vanadium (mg/l)*	26	<0.0055	<0.0068	0.0280	0.0000
Zinc (mg/l)*	27	0.071	0.241	1.250	0.000
Tin (mg/l)*	20	<0.017	<0.010	<0.050	<0.007
Aluminum (mg/l)*	26	<0.026	<0.207	0.110	0.000
Gallium (mg/l)*	20	<0.007	<0.004	0.040	0.000
Germanium (mg/l)*	20	<0.018	<0.010	<0.050	<0.007
Lithium (mg/l)*	27	0.523	0.227	0.960	0.230
Selenium (mg/l)*	26	0.0002	0.0006	0.0020	0.0000
Titanium (mg/l)*	20	<0.011	<0.008	<0.032	<0.004
Zirconium (mg/l)*	20	<0.024	<0.015	<0.070	<0.009
Gross Beta (pc/l, Cs-137)*	21	<8.7	<3.9	<16.0	<4.1
Dissolved Solids (mg/l)*	25	1798.	785.	3400.	875.
Gross Alpha (mg/l U)*	21	<0.026	<0.011	0.056	<0.015
Gross Beta (pc/l SR_{90}/Y_{90})*	21	<7.0	<3.0	13.0	<3.5

*Elements analyzed only for dissolved fraction

[1/] Arithmetic determinations

TABLE II-22

SUMMARY OF GROUND WATER QUALITY
DOUGLAS CREEK AQUIFER
November 26, 1974 - November 11, 1975
G-16A, P-4

Description	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	9	12.8	1.5	15.3	10.5
Conductance (µmhos)	9	1473.	168.	1720.	1300.
Chemical Oxygen Demand (mg/l)	6	104.	111.	260.	7.
pH (pH Units)[1/]	8	9.7	0.7	10.9	9.0
Carbon Dioxide (mg/l)	5	0.3	0.3	0.7	0.0
Alkalinity (mg/l $CACO_3$)	6	677.	137.	817.	500.
Bicarbonate (mg/l HCO_3)	6	652.	88.	753.	522.
Carbonate (mg/l CO_3)	6	85.	53.	138.	0
Filterable Residue (mg/l)	5	1110.	201.	1400.	910.
Oil & Grease (mg/l)	6	2.0	1.5	4	1.
Ammonia (mg/l N)*	6	1.9	1.2	3.5	0.71
Nitrite (mg/l N)*	6	0.003	0.005	0.01	0.00
Nitrate (mg/l N)*	6	0.02	0.04	0.10	0.00
Kjeldahl Nitrogen (mg/l N)	6	2.6	1.9	4.7	0.72
NO_2 + NO_3 (mg/l N)*	6	0.03	0.04	0.10	0.00
Orthophosphate (mg/l PO_4)*	6	0.38	0.14	0.61	0.25
Phosphorous (mg/l)	6	0.16	0.05	0.23	0.09
Orthophosphorous (mg/l P)*	6	0.13	0.05	0.20	0.08
Total Organic Carbon (mg/l)	6	29.	28	57.	3.1
Total Inorganic Carbon (mg/l)	3	37.	65	112.	0.
Sulfide (mg/l)	6	3.0	3.9	10.	0.2
Hardness (mg/l Ca, Mg)	6	41.	57	120.	2.
Non Carbonate Hardness (mg/l)	6	0.	0.	0.	0.
Calcium (mg/l)*	6	3.6	4.0	9.3	0.7
Magnesium (mg/l)*	6	7.4	10.9	22.	0.0
Sodium (mg/l)*	6	362.	34.	430.	340.
Sodium Adsorption Ratio	6	60.	39.	104.	14.
% Sodium	6	95.	6.	100.	87.
Potassium (mg/l)*	6	1.8	1.9	4.5	0.5
Chloride (mg/l)*	6	80.	112.	230.	6.8
Sulfate (mg/l)*	6	32.	39	86.	1.3
Fluoride (mg/l)*	6	1.4	0.7	2.4	0.9
Silica (mg/l)*	6	11.1	4.3	18.	7.9
Arsenic (mg/l)*	6	0.23	0.39	0.950	0.000
Barium (mg/l)*	8	0.15	0.12	0.400	0.040
Beryllium (mg/l)*	8	<0.0035	0.0041	<0.010	0.000
Bismuth (mg/l)*	7	<0.0067	0.0007	<0.008	<0.006
Boron (mg/l)*	8	2.14	2.45	5.20	0.240
Cadmium (mg/l)*	8	0.000	0.000	0.000	0.000
Chromium (mg/l)*	8	<0.0073	0.0033	<0.010	0.000
Cobalt (mg/l)*	8	<0.0034	0.0034	<0.008	0.000
Copper (mg/l)*	8	<0.0034	0.0043	0.014	0.001
Iron (mg/l)*	8	0.077	0.037	0.150	0.040
Lead (mg/l)*	8	<0.003	0.004	<0.008	0.000
Manganese (mg/l)*	8	<0.008	0.007	0.020	0.000
Mercury (mg/l)*	6	<0.00005	0.00005	<0.0001	0.0000
Molybdenum (mg/l)*	8	<0.058	0.098	0.280	0.000
Nickel (mg/l)*	8	<0.008	0.011	0.030	0.000
Silver (mg/l)*	8	<0.0004	0.0005	<0.001	0.000
Strontium (mg/l)*	8	1.71	2.31	5.000	0.040
Vanadium (mg/l)*	8	<0.005	0.004	<0.008	0.000
Zinc (mg/l)*	8	0.015	0.012	0.030	0.000
Tin (mg/l)*	7	<0.006	0.003	<0.011	<0.006
Aluminum (mg/l)*	8	0.016	0.017	0.040	0.000
Gallium (mg/l)*	7	<0.0033	0.0004	<0.004	<0.003
Germanium (mg/l)*	7	<0.009	0.002	<0.011	<0.006
Lithium (mg/l)*	8	0.32	0.29	0.680	0.100
Selenium (mg/l)*	6	0.000	0.000	0.000	0.000
Titanium (mg/l)*	7	<0.005	0.001	<0.007	<0.003
Zirconium (mg/l)*	7	<0.013	0.004	<0.020	<0.009
Gross Beta (pc/l, Cs-137)*	5	<5.92	3.76	10.	<2.7
Dissolved Solids (mg/l)*	6	915.	114.	1040.	797.
Gross Alpha (mg/l U)*	5	0.013	0.003	<0.015	<0.0098
Gross Beta (pc/l SR_{90}/Y_{90})	5	<4.82	3.07	<8.2	<2.2

*Elements analyzed only for dissolved fraction

[1/] Arithmetic determinations

TABLE II-23

SUMMARY OF GROUND WATER QUALITY
UPPER AQUIFER
October 18, 1974 - November 13, 1975
P-2 U

Description	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	8	15.5	1.2	17.5	13.5
Conductance (µmhos)	9	3015.	742.	3700.	1810.
Chemical Oxygen Demand (mg/l)	7	18.	11.	38.	10.
pH (pH Units)[1/]	8	8.2	0.2	8.5	7.9
Carbon Dioxide (mg/l)	8	7.0	3.2	12.0	3.3
Alkalinity (mg/l $CaCO_3$)	9	497.	29	534	434.
Bicarbonate (mg/l HCO_3)	9	606.	36	651	529.
Carbonate (mg/l CO_3)	9	0.	0.	0.	0.
Filterable Residue (mg/l)	6	2680.	390	2900	1900.
Oil & Grease (mg/l)	7	2.	2.	5.	0.
Ammonia (mg/l N)*	8	1.9	0.9	3.9	0.53
Nitrite (mg/l N)*	8	0.01	0.01	0.04	0.00
Nitrate (mg/l N)*	8	0.01	0.01	0.03	0.00
Kjeldahl Nitrogen (mg/l N)	8	2.1	1.3	5.0	0.64
NO_2 + NO_3 (mg/l N)*	8	0.01	0.01	0.03	0.00
Orthophosphate (mg/l PO_4*)	8	0.07	0.07	0.15	0.00
Phosphorous (mg/l)	8	0.03	0.02	0.06	0.02
Orthophosphorous (mg/l P)*	8	0.02	0.02	0.05	0.01
Total Organic Carbon (mg/l)	7	7.9	6.6	19.0	3.0
Total Inorganic Carbon (mg/l)	4	156.	125.	258.	0.
Sulfide (mg/l)	2	9.	12.	18.	1.
Hardness (mg/l Ca, Mg)	9	252.	39.	290.	180.
Non Carbonate Hardness (mg/l)	9	0	0	0	0
Calcium (mg/l)*	9	27.	3.	30.	20.
Magnesium (mg/l)*	9	44.	9.	54.	30.
Sodium (mg/l)*	9	737.	162.	850.	450.
Sodium Adsorption Ratio	9	20.	3.	23.	14.
% Sodium	9	86.	2.	88.	83.
Potassium (mg/l)*	9	3.4	2.9	11.0	1.8
Chloride (mg/l)*	9	60.	14.	82.	36.
Sulfate (mg/l)*	9	1241.	355.	1500.	730.
Fluoride (mg/l)*	9	0.6	0.3	1.1	0.4
Silica (mg/l)*	9	19.	2.	20.	17.
Arsenic (mg/l)*	9	0.012	0.009	0.025	0.001
Barium (mg/l)*	8	< 0.065	< 0.038	< 0.100	0.020
Beryllium (mg/l)*	8	< 0.009	< 0.006	0.020	< 0.004
Bismuth (mg/l)*	6	< 0.018	< 0.003	< 0.025	< 0.015
Boron (mg/l)*	9	0.410	0.260	1.100	0.280
Cadmium (mg/l)*	8	0	0	0	0
Chromium (mg/l)*	8	< 0.007	< 0.006	< 0.016	0.000
Cobalt (mg/l)*	8	< 0.003	< 0.005	< 0.016	0.000
Copper (mg/l)*	9	0.002	0.003	0.007	0.000
Iron (mg/l)*	9	0.112	0.082	0.280	0.010
Lead (mg/l)*	8	< 0.003	< 0.005	< 0.016	0.000
Manganese (mg/l)*	8	0.051	0.035	0.150	0.020
Mercury (mg/l)*	9	< 0.00002	< 0.00004	0.00010	0.00000
Molybdenum (mg/l)*	8	0.034	0.023	0.074	0.011
Nickel (mg/l)*	8	< 0.005	< 0.007	< 0.016	0.000
Silver (mg/l)*	8	< 0.0002	< 0.0007	< 0.002	0.000
Strontium (mg/l)*	9	4.211	0.831	5.100	2.600
Vanadium (mg/l)*	8	0.0010	0.0006	0.0019	0.0000
Zinc (mg/l)*	9	0.023	0.023	0.080	0.000
Tin (mg/l)*	6	< 0.018	< 0.004	< 0.025	< 0.015
Aluminum (mg/l)*	8	0.014	0.011	0.030	0.000
Gallium (mg/l)*	6	< 0.003	< 0.001	< 0.010	< 0.007
Germanium (mg/l)*	6	< 0.019	< 0.004	< 0.024	< 0.015
Lithium (mg/l)*	9	0.303	0.041	0.370	0.240
Selenium (mg/l)*	9	0.0001	0.0003	0.0010	0.0000
Titanium (mg/l)*	6	< 0.010	< 0.004	< 0.015	< 0.008
Zirconium (mg/l)*	6	< 0.023	< 0.009	< 0.035	< 0.015
Gross Beta (pc/l, Cs-137)*	6	< 11.3	< 4.9	< 19.	5.
Dissolved Solids (mg/l)*	9	2444.	533.	2840.	1460.
Gross Alpha (mg/l U)*	6	< 0.029	< 0.007	< 0.037	< 0.016
Gross Beta (pc/l SR90/Y90)	2	0.4	0.0	0.4	0.4

*Elements analyzed only for dissolved fraction

1/Arithmetic determination

LEGEND

NOTE: NUMBER AT TOP OF FIGURE IS TOTAL DISSOLVED SOLIDS IN MG/L.

STIFF DIAGRAM SCALE

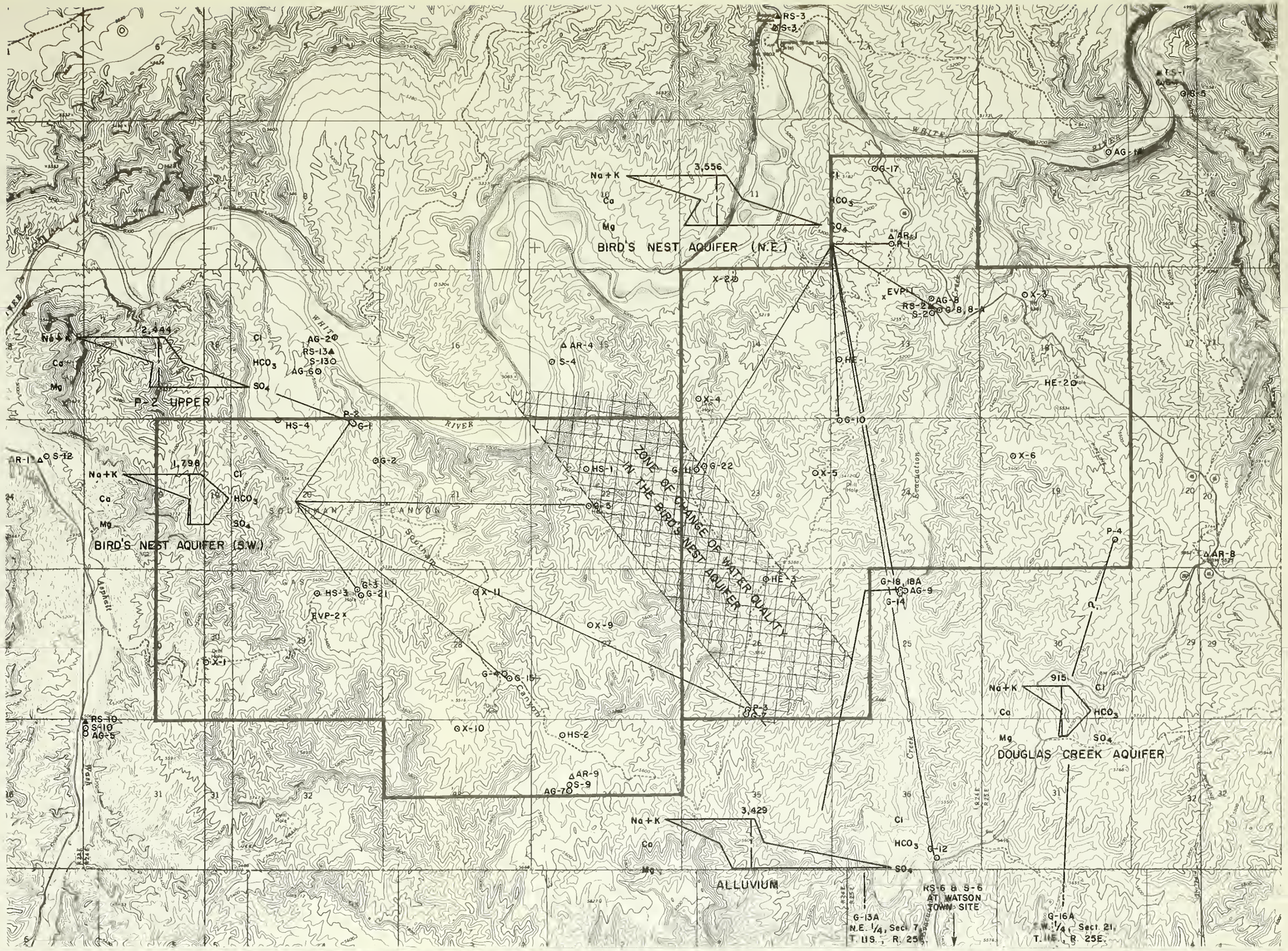
30 20 10 0 10 20 30
MILLIEQUIVALENTS/LITER

- ⊙S SURFACE WATER MONITORING STATION
- ⊙P PILOT TEST HOLE (WATER)
- ⊙G GROUND WATER MONITORING STATION
- ⊙HE EXISTING GEOLOGIC CORE HOLE, EVACUATION
- ⊙HS EXISTING GEOLOGIC CORE HOLE, SOUTHAM
- ⊙X EXPLORATION GEOLOGIC CORE HOLE
- ⊙AG ALLUVIAL WELL (WATER)
- △AR PRECIPITATION, AUTO (WATER)
- ▲RS PRECIPITATION, STORAGE (WATER)
- ×EVP EVAPORATION PAN (WATER)

UTAH

N

1 0 1
SCALE IN MILES



WHITE RIVER SHALE PROJECT

STIFF DIAGRAMS OF WATER QUALITY

MEAN OF ALL SAMPLES NOVEMBER 1974 - DECEMBER 1975

TRACTS U-a-Ub, EASTERN UINTA, UTAH

FIGURE II-64

2. Aquifers underlying the bird's nest may be contributing a better quality of water by upward leakage.

3. There may be hydraulic communication with, and flushing action by, the White River.

4. The same system of recharge and discharge that now occurs in Evacuation Creek Canyon on and near Tract U-b must have existed far up the canyon at different times and locations as the creek was down-cutting. This would have moved water down-dip across U-a, which would have dissolved away much of the nahcolite under Tract U-a without doing so under Tract U-b.

The last is the most plausible explanation in view of the foregoing discussions of flat hydraulic gradient and a 50-fold higher transmissivity under Tract U-a, but any combination of these explanations could account for this phenomenon. In any event the water west of the diagonal line is a sodium-sulfate-bicarbonate ($Na\text{-}SO_4\text{-}HCO_3$) water with an average TDS of 2,540 mg/l; east of the diagonal the water is also a $Na\text{-}SO_4\text{-}HCO_3$ water but with an average TDS of 3,298 mg/l.

In most of the wells the water chemistry of the bird's nest aquifer has fluctuated widely from sample to sample, probably as a result of the differences in sampling and laboratory analysis rather than as a result of naturally occurring chemical changes. At most well locations, the bird's nest water is charged in varying degrees with hydrogen sulfide gas. Samples of pumped water have been collected at the well head in glass jars and allowed to stand exposed to the atmosphere. Within minutes, flocculation and precipitation begin and the pH rises from the original range--7.5-8.5--to a range of from 10 to 11. It is known that rapid chemical changes do occur; therefore, in-line filters (on the pump discharge line) were used in the November-December 1975 sample collections to minimize the exposure time to the air. All other procedures of using preservatives and chilling were followed as before.

Thiefed, or static, samples were collected from time to time in some wells when the pumping equipment was not functioning. The water chemistry analyses of actual concentrations of samples collected in this manner show little resemblance to that of pumped samples, although the ionic distribution remains about the same. The partial historical water chemistry of Well P-1 (Table II-24) shows the differing chemistry of water samples collected by the two methods. Changes similar to those that take place in a sample exposed to air are apparently occurring under static conditions in the borehole.

TABLE II-24

COMPARISON OF BIRDS NEST PARTIAL WATER QUALITY
DIFFERENCES BETWEEN PUMPED AND STATIC SAMPLES
AT THE P-1 SITE

Date	Specific Conductance ($\mu mho/cm^2$)	Total Filtrible Residue (mg/l)	Bicarbonate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TDS (mg/l)
Nov. 20, 1974	5100	4600	543	170	170	930	58	2400	4430
*Dec. 17	1810	1400	303	64	67	310	38	780	1430
Mar. 18, 1975	5200	4800	522	170	190	910	59	2700	4320
May 13	5100	4950	545	170	190	910	56	2500	4350
June 26	4870	4800	536	170	190	910	60	2500	4470
Aug. 17	5170	4800	540	170	210	940	59	2700	4360
Aug. 30	4600	--	453	180	190	940	59	2800	4450
Nov. 14	4750	--	551	130	170	900	62	2400	4380

*December 17, 1974 represents thiefed sample. All others collected by pumping.

h. Ground Water Use

The ground water from the bird's nest aquifer is of limited use because of its quality. The salinity hazard is extremely high, which generally makes the water unfit for most irrigation applications. The sulfates, hardness, and TDS make the water unsuitable for most industrial and domestic uses without treatment.

Shallow alluvial wells supply the southern Uinta Basin with most of the ground water, which is used mainly for stock watering and alternate domestic supplies (Price and Miller 1974). The American Gilsonite Company has drilled about 21 wells in the alluvium of the White River near the Ignacio Stage Stop. The wells supply water for the gilsonite mining operation and for the inhabitants of Bonanza, Utah. A few deep oil and gas wells near the tracts have been converted to stock watering wells.

i. Moisture Monitoring

The moisture monitoring program is intended to supply data concerning the subsurface moisture migration in the first few hundred meters of materials beneath areas expected to be used as processed-shale disposal sites. A quarterly program of neutron logging of selected boreholes was conducted to obtain this information. Since the back-scatter of emitted neutrons is attenuated by the presence of hydrogen atoms, it follows that if the concentration of hydrogen atoms in the formation varies between logging runs, the trace of the neutron log will reflect that variation.

The neutron tool used in this program is designed to have a formation-penetrating depth of about 22 cm (9 in.). Most holes used for the program were originally drilled to about an 20.3 cm (8 in.) diameter into which a 11.4-cm (4.5-in.) O.D. steel casing was set and cemented. The net neutron penetration into the formation was about 17.8 cm (7 in.).

During the drilling phase of the program pump-in type straddle packer tests were run at selected intervals in many of the boreholes. Figure V-4 (Section V.B.2) is an example of the data collected. Generally, the horizontal permeability values determined from tests conducted in the first few hundred meters of the Uinta Formation are quite low. This is in spite of the fact that geophysical logs were used to determine zones of potentially higher permeability for testing.

During the first year of baseline data collection the processed-shale disposal site had not been selected, and consequently many wells were drilled that are no longer needed in the moisture monitoring program now that Southam Canyon has been selected. These wells originally selected for logging include G-1, 2b, 8, 11, 12, 15, 17, 18, 19, 20, 21; P-1, 3, 4; X-3 and X-6. Copies of all logs have been forwarded to the AOSO.

Including the initial neutron logging run completed at the time of drilling during fall 1974 the wells listed above were logged in April, August and December of 1975. It is felt at this time that logs completed at the time of drilling are of little value because the entire length of the borehole walls were subjected to wetting by circulating drilling fluids and produced water. Selected intervals were subjected to pump-in type of straddle packer testing closely following logging. The April 1975 logs are not considered by Birdwell (contractor) to be valuable or even indicative of formation conditions because the specialized tool, newly acquired for this job, yielded results that Birdwell felt were not up to the standards of their company. The August and December runs were made using the standard oil-field tool that was used to log geological exploration holes drilled on the tracts, but outside the ground water exploration program. At Birdwell's laboratory the tool is calibrated by established standards prior to each run. The operator, recording equipment, and trolling speeds are maintained from run to run.

Minor differences in the neutron log trace are discernible in comparing the April and December 1975 logging runs of each hole. The differences reflect very small increases and decreases of moisture content in the borehole walls. Some wells indicate no change. At this time, no discernible patterns have emerged on an aerial basis. Some wells indicate increases throughout intervals of 30.5 m (100 ft) or more, which may actually reflect an imperfect grout seal. Moisture would not be expected to move that rapidly downward through the near surface strata unless that particular length of the borehole happened to align with a fracture.

In fact, even if a pattern had emerged given the expected very slow vertical migration of moisture (except along fractures), it is entirely probable that changes could be in response to a climatic event that occurred some time ago; however, the small amounts of moisture that appear to migrate vertically through these strata cannot be correlated definitely with past historical climatic events, and therefore it is not known when this monitored moisture entered the strata or how long it has taken to achieve its present depth.

It was established that two sets of joints in the rocks are the dominant secondary structural features in the area. The principal set trends northwest and the other trends northeast at near right angles to the first. All have near vertical dip (Section V.B.3). Fracture filling of varying degrees is common to all joint sets. For this reason it is more plausible that most of the moisture enters the bedrock surface through fractures, and from there continues downward as long as there is no resistence. If the migration route is obstructed at some point, the moisture continues downward by another route. The migration of moisture is such that the moisture pulse from any one storm or seasonal increase is irregularly distributed; as a result some wells show no change in moisture, some show increases, some show decreases, and others fluctuate in different parts of the penetrated stratigraphic section.

There is no question that moisture penetrates the Uinta Formation in Southam Canyon, as shown by the occurrence of short-lived spring-time seeps in some locations and widespread occurrences of a white salt along bedding planes and fractures in other locations, but it is doubtful either that quantitative determinations of volume or rates and direction of flow can be determined from this program or that a meaningful program of detection and determination of moisture migration in the bedrock can be developed. It is therefore recommended that the program be deleted from the baseline data collection program.

D. CONCLUSIONS

Several conclusions may be drawn from the data regarding the interrelationships of surface and ground water. The bird's nest aquifer is known to crop out continuously in the bed of Evacuation Creek from a point about 3.65 km (2.25 mi) south of Tract U-b to the north edge of Tract U-b. Throughout the first 2.4 km to 3.2 km (1.5 mi to 2 mi), the aquifer apparently receives recharge from the stream and its alluvium; beyond that distance the aquifer discharges back to the stream and its alluvium. Most of this discharge passes the S-2 gaging station on Evacuation Creek, where baseflows of 28.3 l/s to 42.4 l/2 (1.0 cfs to 1.5 cfs) were recorded during fall 1974 and 1975. Discharge from the aquifer occurs for about another 0.8 km (0.5 mi) downstream of S-2, and the total discharge may be in the range of 56.6 l/s (2.0 cfs). The flow eventually discharges to the White River.

About 0.8 km (0.5 mi) downstream of the confluence of the White River and Evacuation Creek (Sec. 12, T10S, R24E) the river channel cuts through the bird's nest aquifer, and the aquifer discharges into the river at this location. This discharge is not of sufficient quantity to be monitored in the established flow records at S-1 and S-3, situated on either side of the discharge point. The water quality records obtained at these stations do not reflect the aquifer water discharged to the river despite the fact that at certain times the TDS concentrations in the ground water may be ten times greater than those in the river water.

Another point of hydraulic communication may be the Green River where it flows from the Uinta Basin, near Ouray, but this interconnection has not been established. No other points of interconnection of stream and aquifer have been established on or near the tracts.

E. WORK SCHEDULED

1. SURFACE WATER HYDROLOGY

All segments of the program (surface water hydrology and quality, precipitation, and evaporation data collection) are expected to continue uninterrupted through the second year of the program, as directed by the AOSS.

2. GROUND WATER HYDROLOGY

The aquifer-test phase of the baseline data collection program is complete. Routine collection of water-level and water-quality data will continue throughout the baseline program.

Moisture monitoring, if continued, will be concentrated in Southam Canyon to determine whether disposal of processed shale at this site will disturb the ground water hydrology.

GLOSSARY

Aquifer: a saturated bed, formation, or group of formations which yields water in sufficient quantity to be of consequence as a source of supply.

Alluvium: a general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope. Syn: alluvial, alluvial deposit.

Artesian head: the hydrostatic head or height of a vertical column of water, the weight of which, if of unit cross-section, is equal to the hydrostatic pressure at a point of an artesian aquifer or of the water in the aquifer.

Diurnal variation: variation throughout daylight hours.

Evapotranspiration: loss of water from a land area through transpiration of plants and evaporation from the soil. Also, the volume of water lost through evapotranspiration.

Formation: the basic or fundamental rock-stratigraphic unit in the local classification of rocks, consisting of a body of rock generally characterized by some degree of internal lithologic homogeneity or distinctive lithologic features such as chemical composition, structures, textures, or gross aspect of fossils, by a prevailingly but not necessarily tabular shape, and by mappability at the earth's surface. Syn: geologic formation.

Geophysical log: a log obtained by lowering an instrument into a borehole or well and recording continuously on a meter at the surface some physical property of rock material being logged.

Incised: in geomorphology, said of a stream meander or notch that has downcut or entrenched into the surface during, and because of, relative uplift of the surface.

Isotropic: said of a medium whose properties are the same in all directions.

Member: a rock-stratigraphic unit of subordinate rank, comprising some specially developed part of a varied formation such as a lithologically unified subdivision distinguished from adjacent parts of the formation by color, hardness, composition, or similar features and not defined by specified shape or extent.

Potentiometric surface: an imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well. Syn: piezometric surface, isopotential level, pressure surface.

Resistivity: a measure of varying resistance to an electric current of the sequence of rock units opposite the traveling electrode. It is used to determine the nature of the strata penetrated.

Specific conductance: the electrical conductance, measured in μmhos, is the inverse of electrical resistance.

Spontaneous-potential: potential at different depths of a borehole used to indicate porosity and permeability of the rocks penetrated.

Transmissivity: in an aquifer, the rate at which water of the prevailing viscosity is transmitted through a unit width under a unit hydraulic gradient. Though spoken of as a property of the aquifer, it embodies also the saturated thickness and the properties of the contained liquid.

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APPENDICES

APPENDIX II-1

SUMMARY OF THE
STATE OF UTAH WATER
QUALITY STANDARDS
(Class "C" Streams)

Dissolved Oxygen	≥5.5 mg/l
pH	6.5-8.5
Biochemical Oxygen Demand (BOD)	< 5 mg/l monthly mean <10 mg/l any one sample
Total Coliforms	<5000/100 ML monthly mean <20,000/100 ML upper 5% of samples
Fecal Coliforms	<2000/100 ML monthly mean
Chemical Standards	As in U.S. Public Health Service Drinking Water Standards, 1962

Substances cannot be discharged that cause objectionable deposits, floating debris, oil or scum; objectionable color, odor, taste or turbidity; toxic or undesirable responses in humans, fish, other animal life, or plants; or interference with the water's use for irrigation, livestock, drinking water, recreation (except swimming), or fish habitat.

APPENDIX II-2

SUMMARY OF
UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS, 1962

Element	Standard mg/l	Recommended Limits
Arsenic	0.05	0.01
Barium	1.0	
Cadmium	0.01	
Hexavalent Chromium	0.05	
Cyanide	0.2	0.01
Fluoride	1.0*	0.8*
Lead	0.05	
Selenium	0.01	
Silver	0.05	
ABS		0.5
Chloride		250.0
Copper		1.0
CCE		0.2
Iron		0.3
Manganese		0.05
Nitrate		45.0
Phenols		0.001
Sulfate		250.0
Dissolved Solids		500.0
Zinc		5.0
Turbidity		5
Color		15
Odor		3

APPENDIX II-3

SUMMARY
NATIONAL ACADEMY OF SCIENCES
WATER QUALITY CRITERIA
Concentrations in mg/l

	Agriculture	Livestock	Aquatic Life	Wildlife	Water Supply
Aluminum	5.0	5.0			
Ammonia			0.02 unionized		0.5
Arsenic	0.1	0.2			0.1
Barium					1.0
Beryllium	0.1				
Bicarbonate Alkalinity				130	
Boron	0.75	5.0			1.0
Cadmium	0.01	0.05	0.03		0.01
Chlorides			.003 Residual		250.0
Chromium	0.1	1.0	0.05		0.05
Cobalt	0.05	1.0			
Coliform, Fecal	1000/100 ml				
Color					
Copper	0.2	0.5	1/10 96HR LC_{50}*		1.0
Cyanide			1/20 96HR LC_{50}*		
Dissolved Solids	500-1000	3000			
Detergents			1/20 96HR LC_{50}*		
Fluoride	1.0	2.0			1.4
Iron	5.0				0.3
LAS			1/20 96HR LC_{50}*		
Lead	5.0	0.1	0.03		0.05
Lithium	2.5				
Manganese	0.2				0.05
Mercury		0.01	0.00005		0.002
Molybdenum	0.01				
Nickel	0.2		1/50 96HR LC_{50}*		
Nitrates		100.0 }	total 10 alone		10.0
Nitrites		100.0 }			1.0
Oil			1/20 96HR LC_{50}*		
pH	4.5-9.0		6.0-9.0	6.0-9.0	5.0-9.0
Phenolcs			0.1		0.001
Polychlorinated Biphenols			0.000002		
Pthalate Esters			0.0003		
Salinity					
Selenium	0.02	0.05			0.01
Silver					0.05
Sodium					
Sulfate					250.0
Sulfide			0.002		
Suspended & Settleable Solids			25-400		
Vanadium	0.1	0.1			
Zinc	2.0	25.0	1/200 96HR LC_{50}*		5.0

*Concentration letal to 50% of the most sensitive local aquatic organisms during 96 hours of contact.

APPENDIX II-4

SUMMARY OF WATER QUALITY

WHITE RIVER ABOVE HELLS HOLE CANYON (S-1)

AUGUST 1974 THRU MAY 6, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	17	5.6	6.5	18	0
Turbidity (JTU)	12	74	113	1200	6
Conductance (umhos)	17	829	55	927	480
Chemical Oxygen Demand (mg/l)	17	10	8	140	0
pH (pH Units)	10	8.2	0.3	8.5	7.8
Carbon Dioxide (mg/l)	10	3.0	1.9	6.7	1.1
Alkalinity (mg/l $CACO_3$)	17	200	13	228	127
Bicarbonate (mg/l HCO_3)	17	240	19	266	155
Carbonate (mg/l CO_3)	17	1.7	5.4	22	0
Filterable Residue (mg/l)	8	555	47	630	510
Oil & Grease (mg/l)	15	3	3	11	0
Ammonia (mg/l N)*	17	0.06	0.07	.29	.00
Nitrite (mg/l N)*	17	0.00	0.01	.01	.00
Nitrate (mg/l N)*	16	0.13	0.15	.50	.00
Kjeldahl Nitrogen (mg/l N)	17	0.43	0.30	4.9	.03
NO_2 + NO_3 (mg/l N)*	17	0.12	0.15	.51	.00
Orthophosphate (mg/l PO_4)*	17	0.05	0.05	.12	.00
Phosphorous (mg/l)	17	0.10	0.11	.47	.01
Orthophosphorous (mg/l P)*	17	0.02	0.02	.04	.00
Total Organic Carbon (mg/l)	3	3.8	1.7	5.5	3.7
Total Inorganic Carbon (mg/l)	1	38	-	-	-
Cyanide (mg/l)	9	0.00	0.00	.01	.00
Sulfide (mg/l)*	17	0.25	0.59	2.5	.0
Hardness (mg/l Ca, Mg)	17	288	23	320	170
Non Carbonate Hardness (mg/l)	17	87	17	120	45
Calcium (mg/l)*	17	70	6	83	41
Magnesium (mg/l)*	17	27	3	32	17
Sodium (mg/l)*	17	74	12	110	30
Sodium Adsorption Ratio	17	1.9	0.3	2.9	1.0
% Sodium	17	36	3	46	27
Potassium (mg/l)*	17	2.4	0.9	4.0	.9
Chloride (mg/l)*	17	42	9	68	12
Sulfate (mg/l)*	17	178	19	210	84
Fluoride (mg/l)*	17	0.3	0.1	.4	.2
Silica (mg/l)*	17	13	1.7	17	11
Arsenic (mg/l)*	10	0.0016	0.0012	.004	.000
Barium (mg/l)*	10	<0.1	-	<.1	-
Beryllium (mg/l)*	3	<0.01	-	<.01	-
Bismuth (mg/l)*	1	<0.01	-	<.01	-
Boron (mg/l)*	10	0.069	0.025	.120	.040
Cadmium (mg/l)*	10	<0.001	-	<.001	-
Chromium (mg/l)*	10	<0.01	-	<.02	-
Cobalt (mg/l)*	10	<0.001	-	<.001	-
Copper (mg/l)*	10	0.004	0.007	.020	.000
Iron (mg/l)*	10	0.021	0.012	.040	.010
Lead (mg/l)*	10	0.001	0.001	.003	.000
Manganese (mg/l)*	10	<0.01	-	.02	-
Mercury (mg/l)*	10	<.00007	-	.0003	
Molybdenum (mg/l)*	10	0.0025	0.0014	.005	.000
Nickel (mg/l)*	10	0.0046	0.0054	.016	.000
Silver (mg/l)*	3	0.000	0.000	0	0
Strontium (mg/l)*	3	1.02	0.68	1.100	.970
Vanadium (mg/l)*	10	0.0015	0.0016	.0051	.000
Zinc (mg/l)*	10	0.030	0.05	.180	.000
Tin (mg/l)*	1	<0.01	-	<.01	-
Aluminum (mg/l)*	10	<0.01	-	.02	-
Gallium (mg/l)*	1	<0.005	-	<.005	-
Germanium (mg/l)*	1	<0.01	-	<.01	-
Lithium (mg/l)*	10	<0.018	-	.03	-
Selenium (mg/l)*	9	0.001	0.0005	.002	.001
Titanium (mg/l)*	1	<0.008	-	<.008	-
Zirconium (mg/l)*	1	<0.018	-	<.018	-
Gross Beta (mg/l Cs_{137})*	8	0.004	0.001	.0056	.0025
Chlorophyll A (mg/l)	8	0.0023	0.0014	.0044	.008
Chlorophyll B (mg/l)	8	0.0027	0.0019	.0057	.006
Phenols (mg/l)	16	0.0026	0.0028	.0010	.000
Dissolved Solids (mg/l)*	17	543	43	626	310
Gross Alpha (mg/l U)*	8	<0.009	-	.013	-
Gross Beta (mg/l Sr_{90}/Y_{90})*	8	0.0033	0.001	.0047	.002

* Elements analyzed only for dissolved fraction.

APPENDIX II-5

SUMMARY OF WATER QUALITY

WHITE RIVER NEAR WATSON (S-3)

AUGUST 1974 - MAY 5, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (^{o}C)	19	8.0	9.1	28.5	0
Turbidity (JTU)	12	128	205	680	5
Conductance (umhos)	20	834	94	1,010	630
Chemical Oxygen Demand (mg/l)	17	10	10	38	0
pH (pH Units)	14	8.2	0.2	8.6	7.9
Carbon Dioxide (mg/l)	4	2.4	1.0	4.6	1.5
Alkalinity (mg/l $CACO_3$)	20	199	17	236	172
Bicarbonate (mg/l HCO_3)	20	241	21	288	208
Carbonate (mg/l CO_3)	18	0.2	0.7	3	0
Filterable Residue (mg/l)	8	580	68	690	500
Oil & Grease (mg/l)	16	3	.2	6	0
Ammonia (mg/l N)*	18	0.06	0.05	.19	.01
Nitrite (mg/l N)*	17	0.00	0.00	.01	.00
Nitrate (mg/l N)*	16	0.13	0.14	.39	.00
Kjeldahl Nitrogen (mg/l N)	20	0.36	0.23	.94	.10
NO_2 + NO_3 (mg/l N)*	20	0.13	0.13	.37	.00
Orthophosphate (mg/l PO_4)*	20	0.06	0.04	.15	.00
Phosphorous (mg/l)	17	0.12	0.17	.74	.00
Orthophosphorous (mg/l P)*	20	0.02	0.01	.04	.00
Total Organic Carbon (mg/l)	3	7.2	5.0	13	4.1
Total Inorganic Carbon (mg/l)	1	32	-	-	-
Cyanide (mg/l)	9	0.00	0.00	.01	.00
Sulfide (mg/l)*	17	0.1	0.1	.3	.0
Hardness (mg/l Ca, Mg)	20	299	44	460	270
Non Carbonate Hardness (mg/l)	20	100	40	260	72
Calcium (mg/l)*	20	72	12	120	60
Magnesium (mg/l)*	20	29	4	39	24
Sodium (mg/l)*	20	78	16	120	60
Sodium Adsorption Ratio	20	2.0	0.3	2.7	1.0
% Sodium	20	36	2.3	40	28
Potassium (mg/l)*	20	2.3	0.5	2.8	1.0
Chloride (mg/l)*	20	42	10	79	13
Sulfate (mg/l)*	20	188	26	250	81
Fluoride (mg/l)*	20	0.3	0.1	.4	.2
Silica (mg/l)*	20	13	2	17	10
Arsenic (mg/l)*	10	0.002	0.001	0.004	0
Barium (mg/l)*	10	<0.100	-	< .1	-
Beryllium (mg/l)*	4	<0.01	-	< .01	-
Bismuth (mg/l)*	2	<0.01	-	< .011	-
Boron (mg/l)*	12	.088	0.026	.130	-
Cadmium (mg/l)*	10	<0.001	-	< .001	-
Chromium (mg/l)*	11	<0.01	-	< .01	-
Cobalt (mg/l)*	11	<0.001	-	< .001	-
Copper (mg/l)*	10	0.003	0.002	.006	.001
Iron (mg/l)*	9	0.023	0.011	.270	.010
Lead (mg/l)*	10	0.001	0.001	.002	.000
Manganese (mg/l)*	10	0.009	0.011	.030	.000
Mercury (mg/l)*	10	0.00003	0.00007	.0002	.0000
Molybdenum (mg/l)*	10	0.003	0.001	.004	.001
Nickel (mg/l)*	10	0.003	0.004	.012	.000
Silver (mg/l)*	4	<0.001	-	<.001	-
Strontium (mg/l)*	4	1.010	0.064	1.100	.950
Vanadium (mg/l)*	10	0.0015	0.0013	.0042	.00
Zinc (mg/l)*	10	<0.025	0.031	.110	.010
Tin (mg/l)*	2	0.01	-	<.011	-
Aluminum (mg/l)*	10	0.018	0.015	.050	.00
Gallium (mg/l)*	2	<0.005	-	<.005	-
Germanium (mg/l)*	2	<0.011	-	<.011	-
Lithium (mg/l)*	10	<0.015	-	.03	-
Selenium (mg/l)*	9	<0.001	0.001	.002	.001
Titanium (mg/l)*	2	<0.008	-	<.008	-
Zirconium (mg/l)*	2	<0.018	-	<.018	-
Gross Beta (mg/l Cs_{137})*	6	0.0055	0.0031	.012	.00
Chlorophyll A (mg/l)	6	0.0024	0.0021	.0058	.0003
Chlorophyll B (mg/l)	6	0.0011	0.0007	.0025	.0005
Phenols (mg/l)	14	0.0029	0.0024	.006	.00
Dissolved Solids (mg/l)*	17	551	54	676	278
Gross Alpha (mg/l U)*	8	<0.014	-	.035	-
Gross Beta (mg/l Sr_{90}/Y_{90})*	8	0.0049	0.003	9.9	2.4

* Elements analyzed only for dissolved fraction.

APPENDIX II-6

SUMMARY OF WATER QUALITY

WHITE RIVER ABOVE SOUTHAM CANYON (S-4)

AUGUST 1974 - MAY 6, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	17	5.4	6.1	18.0	0
Turbidity (JTU)	12	120	167	1400	7
Conductance (umhos)	17	848	98	1100	425
Chemical Oxygen Demand (mg/l)	17	15	12	150	3
pH (pH Units)	11	8.1	0.2	8.5	7.8
Carbon Dioxide (mg/l)	11	3.3	1.5	5.6	1.2
Alkalinity (mg/l $CaCO_3$)	17	202	16	242	126
Bicarbonate (mg/l HCO_3)	12	246	20	295	153
Carbonate (mg/l CO_3)	17	0	1	3	0
Filterable Residue (mg/l)	7	587	77	710	510
Oil & Grease (mg/l)	14	3	2	180	0
Ammonia (mg/l N)*	17	0.05	0.04	.12	.00
Nitrite (mg/l N)*	17	0.01	0.01	.04	.00
Nitrate (mg/l N)*	15	0.14	0.12	1.1	.00
Kjeldahl Nitrogen (mg/l N)	17	0.50	0.38	4.6	.03
NO_2 + NO_3 (mg/l N)*	16	0.12	0.13	1.1	.00
Orthophosphate (mg/l PO_4)*	17	0.05	0.05	.15	.00
Phosphorous (mg/l)	17	0.12	0.12	1.4	.00
Orthophosphorous (mg/l P)*	17	0.02	0.02	.05	.00
Total Organic Carbon (mg/l)	3	6.0	2.6	8.0	3.1
Total Inorganic Carbon (mg/l)	1	17	---	---	---
Cyanide (mg/l)	9	0.00	0.00	.01	.00
Sulfide (mg/l)*	17	0.2	0.3	1.3	.00
Hardness (mg/l Ca, Mg)	17	294	27	340	180
Non Carbonate Hardness (mg/l)	17	91	16	120	52
Calcium (mg/l)*	17	71	6	82	43
Magnesium (mg/l)*	17	28	4	36	17
Sodium (mg/l)*	17	77	17	130	30
Sodium Adsorption Ratio	17	1.9	0.4	3.2	1.0
% Sodium	17	36	0.4	47	27
Potassium (mg/l)*	17	2.4	0.8	5.0	1.1
Chloride (mg/l)*	17	45	20	120	14
Sulfate (mg/l)*	17	186	27	260	83
Fluoride (mg/l)*	17	0.2	0.1	.3	.0
Silica (mg/l)*	17	13	2	17	11
Arsenic (mg/l)*	10	1.5	0.7	2	0
Barium (mg/l)*	10	<0.1	---	<.1	---
Beryllium (mg/l)*	5	<0.01	---	<.01	---
Bismuth (mg/l)*	3	<0.01	---	<.012	---
Boron (mg/l)*	10	0.079	0.022	.130	.050
Cadmium (mg/l)*	10	<0.001	---	<.001	---
Chromium (mg/l)*	10	<0.01	---	<.01	---
Cobalt (mg/l)*	10	<0.001	---	<.001	---
Copper (mg/l)*	10	0.041	0.065	.160	.000
Iron (mg/l)*	10	0.042	0.031	.100	.010
Lead (mg/l)*	10	0.0008	0.001	.003	.000
Manganese (mg/l)*	10	0.006	0.007	.020	.00
Mercury (mg/l)*	10	0.004	0.001	.005	.000
Molybdenum (mg/l)*	10	<0.00009	-	.0004	
Nickel (mg/l)*	10	0.004	0.005	.016	.000
Silver (mg/l)*	5	<0.005	---	<.002	---
Strontium (mg/l)*	5	1.08	0.134	1.300	.980
Vanadium (mg/l)*	10	0.002	0.001	.0048	.000
Zinc (mg/l)*	10	0.014	0.01	.030	.000
Tin (mg/l)*	3	<0.01	---	<.01	---
Aluminum (mg/l)*	10	0.021	0.026	.080	.00
Gallium (mg/l)*	3	<0.005	---	<.005	---
Germanium (mg/l)*	3	<0.01	---	<.01	---
Lithium (mg/l)*	10	<0.02	---	.03	---
Selenium (mg/l)*	9	0.002	0.001	.004	.001
Titanium (mg/l)*	3	<0.008	---	<.008	---
Zirconium (mg/l)*	3	<0.02	---	<.02	---
Gross Beta (mg/l Cs_{137})*	7	0.0048	0.0024	.0096	.0038
Chlorophyll A (mg/l)	6	0.0030	0.0026	.0071	.0
Chlorophyll B (mg/l)	6	0.0020	0.0022	.0056	.0
Phenols (mg/l)	16	0.0033	0.0025	.007	.0
Dissolved Solids (mg/l)*	17	556	65	717	291
Gross Alpha (mg/l U)*	7	<0.011	---	.012	---
Gross Beta (mg/l SR_{90}/Y_{90})*	7	0.0042	0.0021	8.0	1.6

* Elements analyzed only for dissolved fraction.

APPENDIX II-7

SUMMARY OF WATER QUALITY

WHITE RIVER BELOW ASPHALT WASH (S-11)

AUGUST 1974 THRU APRIL 23, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (^{o}C)	15	6	7	19.0	0
Turbidity (JTU)	11	97	153	760	8
Conductance (umhos)	16	892	218	1650	425
Chemical Oxygen Demand (mg/l)	16	13	9	33	2
pH (pH Units)	8	8.3	0.3	8.6	7.6
Carbon Dioxide (mg/l)	8	2.8	2.0	8.2	1.0
Alkalinity (mg/l $CACO_3$)	16	204	13	230	133
Bicarbonate (mg/l HCO_3)	16	248	17	280	162
Carbonate (mg/l CO_3)	16	0	1	5	0
Filterable Residue (mg/l)	6	590	51	650	450
Oil & Grease (mg/l)	15	3	2	7	0
Ammonia (mg/l N)*	16	0.06	0.05	.15	.00
Nitrite (mg/l N)*	16	0.00	0.01	.02	.00
Nitrate (mg/l N)*	15	0.14	0.16	.52	.00
Kjeldahl Nitrogen (mg/l N)	16	0.37	0.21	2.5	.04
NO_2 + NO_3 (mg/l N)*	16	0.14	0.16	.54	.00
Orthophosphate (mg/l PO_4)*	16	0.05	0.04	.12	.00
Phosphorous (mg/l)	16	0.08	0.06	.20	.00
Orthophosphorous (mg/l P)*	16	0.02	0.01	.04	.00
Total Organic Carbon (mg/l)	3	6.23	1.62	7.7	4.5
Total Inorganic Carbon (mg/l)	1	33	-	-	-
Cyanide (mg/l)	8	0.00	0.00	.01	.00
Sulfide (mg/l)*	16	0.15	0.32	1.3	.0
Hardness (mg/l Ca, Mg)	16	299	22	330	170
Non Carbonate Hardness (mg/l)	16	94	15	120	38
Calcium (mg/l)*	16	72	5	83	42
Magnesium (mg/l)*	16	29	4	36	16
Sodium (mg/l)*	16	80	28	180	32
Sodium Adsorption Ratio	16	2.0	0.7	4.4	1.1
% Sodium	16	36	5	54	29
Potassium (mg/l)*	16	2.4	1.1	6.1	1.1
Chloride (mg/l)*	15	42	6	230	12
Sulfate (mg/l)*	16	188	22	220	95
Fluoride (mg/l)*	16	0.2	0.1	.3	.1
Silica (mg/l)*	16	14	2	17	11
Arsenic (mg/l)*	9	0.001	0.001	.003	.000
Barium (mg/l)*	9	<0.1	-	<.1	-
Beryllium (mg/l)*	4	<0.01	-	<.01	-
Bismuth (mg/l)*	2	<0.015	-	<.015	-
Boron (mg/l)*	9	0.093	0.038	.190	.060
Cadmium (mg/l)*	9	<0.001	-	.001	-
Chromium (mg/l)*	9	<0.01	-	.01	-
Cobalt (mg/l)*	9	<0.001	-	.001	-
Copper (mg/l)*	7	0.003	0.002	.340	.001
Iron (mg/l)*	9	0.04	0.05	.140	.010
Lead (mg/l)*	9	<0.002	-	.007	-
Manganese (mg/l)*	9	<0.01	-	.01	-
Mercury (mg/l)*	9	<0.00007	-	.0003	-
Molybdenum (mg/l)*	9	0.0028	0.0010	.004	.001
Nickel (mg/l)*	9	<0.014	-	.016	-
Silver (mg/l)*	4	<0.002	-	<.002	-
Strontium (mg/l)*	4	1.1	0.14	1.300	1.000
Vanadium (mg/l)*	9	0.0011	0.0008	.002	.0
Zinc (mg/l)*	9	0.032	0.04	.130	.006
Tin (mg/l)*	2	<0.01	-	<.012	-
Aluminum (mg/l)*	9	<0.02	-	.06	-
Gallium (mg/l)*	2	<0.005	-	<.006	-
Germanium (mg/l)*	2	<0.011	-	<.017	-
Lithium (mg/l)*	9	<0.02	-	<.11	-
Selenium (mg/l)*	7	0.0016	0.0005	.002	.001
Titanium (mg/l)*	2	<0.008	-	<.008	-
Zirconium (mg/l)*	2	<0.02	-	<.02	-
Gross Beta (mg/l Cs_{137})*	6	0.0044	0.0022	.0084	.0025
Chlorophyll A (mg/l)	7	0.0025	0.0022	.0060	.000
Chlorophyll B (mg/l)	7	0.0019	0.0030	.0084	.000
Phenols (mg/l)	15	0.0035	0.0037	.014	.000
Dissolved Solids (mg/l)*	16	579	101	892	293
Gross Alpha (mg/l U)*	6	<0.012	-	.031	-
Gross Beta (mg/l SR_{90}/Y_{90})*	6	0.0036	0.0019	7.2	2.1

* Elements analyzed only for dissolved fraction.

APPENDIX II-8

SUMMARY OF WATER QUALITY

EVACUATION BELOW PARK CANYON (S-7)

NOVEMBER 1974 TO JANUARY 8, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	4	3.7	4.0	8.0	.0
Turbidity (JTU)	4	2.0	0.8	3	1
Conductance (umhos)	5	4014	374	4110	3400
Chemical Oxygen Demand (mg/l)	5	24	6	33	20
pH (pH Units)	3	8.2	0.1	8.3	8.1
Carbon Dioxide (mg/l)	3	5.2	1.1	5.9	4.0
Alkalinity (mg/l $CaCO_3$)	5	407	41	469	384
Bicarbonate (mg/l HCO_3)	5	496	50	572	439
Carbonate (mg/l CO_3)	5	0	0	0	0
Filterable Residue (mg/l)	3	3770	150	3900	3600
Oil & Grease (mg/l)	5	2	5	11	0
Ammonia (mg/l N)*	5	0.06	0.04	.11	.02
Nitrite (mg/l N)*	5	0.03	0.01	.04	.01
Nitrate (mg/l N)*	5	5.6	3.5	8.8	.01
Kjeldahl Nitrogen (mg/l N)	5	0.79	0.29	1.3	.59
NO_2 + NO_3 (mg/l N)*	5	5.6	3.5	8.8	.03
Orthophosphate (mg/l PO_4)*	5	0.05	0.03	.09	.03
Phosphorous (mg/l)	5	0.04	0.07	.16	.01
Orthophosphorous (mg/l P)*	5	0.02	0.01	.03	.01
Total Organic Carbon (mg/l)	1	15	---	---	---
Total Inorganic Carbon (mg/l)	0	---	---	---	---
Cyanide (mg/l)	3	0.00	0.00	.00	.00
Sulfide (mg/l)*	5	0.50	1.01	2.3	.0
Hardness (mg/l Ca, Mg)	5	1116	115	1300	980
Non Carbonate Hardness (mg/l)	5	708	74	820	620
Calcium (mg/l)*	5	172	16	200	160
Magnesium (mg/l)*	5	166	18	190	140
Sodium (mg/l)*	5	648	40	700	590
Sodium Adsorption Ratio	5	85	0.6	9.4	7.8
% Sodium	5	56	3	59	52
Potassium (mg/l)*	5	4.4	1.8	5.9	1.4
Chloride (mg/l)*	5	38	3	43	35
Sulfate (mg/l)*	5	1940	89	2000	1800
Fluoride (mg/l)*	5	1.3	0.5	2.1	.9
Silica (mg/l)*	5	15	7	27	9.4
Arsenic (mg/l)*	3	.002	1	2	1
Barium (mg/l)*	3	<0.1	---	<.1	---
Beryllium (mg/l)*	1	<0.01	---	<.01	---
Bismuth (mg/l)*	1	<0.06	---	<.06	---
Boron (mg/l)*	3	1.7	608	2.4	1.3
Cadmium (mg/l)*	3	0	---	0	---
Chromium (mg/l)*	3	<0.01	---	<.01	---
Cobalt (mg/l)*	3	<0.001	---	.001	---
Copper (mg/l)*	3	0.003	0.001	.004	.002
Iron (mg/l)*	3	0.017	0.006	.020	.010
Lead (mg/l)*	3	0.001	0.002	.003	.000
Manganese (mg/l)*	3	0.037	0.006	.042	.030
Mercury (mg/l)*	3	0.00013	0.00015	.0003	.0000
Molybdenum (mg/l)*	3	0.048	0.016	.067	.038
Nickel (mg/l)*	3	0.011	0.005	.016	.006
Silver (mg/l)*	1	0	---	---	---
Strontium (mg/l)*	1	4.100	---	---	---
Vanadium (mg/l)*	3	0.001	0.001	.0025	.000
Zinc (mg/l)*	3	0.013	0.006	.0020	.0010
Tin (mg/l)*	1	<0.06	---	<.06	---
Aluminum (mg/l)*	3	0	---	---	---
Gallium (mg/l)*	1	<0.03	---	<.03	---
Germanium (mg/l)*	1	<0.06	---	<.06	---
Lithium (mg/l)*	3	0.103	0.032	.140	.080
Selenium (mg/l)*	3	0.011	0.008	.020	.006
Titanium (mg/l)*	1	<0.04	---	<.04	---
Zirconium (mg/l)*	1	<0.1	---	<.1	---
Gross Beta (mg/l Cs_{137})*	3	<0.014	---	.017	---
Chlorophyll A (mg/l)	2	0.0008	0.0008	.0013	.0002
Chlorophyll B (mg/l)	2	0.0007	0.0005	.0010	.0003
Phenols (mg/l)	5	0.001	0.000	.001	.000
Dissolved Solids (mg/l)*	3	3606	166	3790	3360
Gross Alpha (mg/l U)*	3	<0.05	---	<.05	---
Gross Beta (mg/l SR_{90}/Y_{90})*	3	<0.012	---	.014	---

* Elements analyzed only for dissolved fraction.

APPENDIX II-9

SUMMARY OF WATER QUALITY

EVACUATION CREEK AT WATSON (S-6)

SEPTEMBER 1974 THRU FEBRUARY 18, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	9	4.0	3.7	10.5	.8
Turbidity (JTU)	6	11.5	11.3	30	3
Conductance (umhos)	9	5616	387	6170	5000
Chemical Oxygen Demand (mg/l)	9	44	7.6	59	34
pH (pH Units)	4	7.9	0.3	8.2	7.7
Carbon Dioxide (mg/l)	4	13.1	8.0	21	5.8
Alkalinity (mg/l $CACO_3$)	9	472	27	527	434
Bicarbonate (mg/l HCO_3)	9	575	33	642	525
Carbonate (mg/l CO_3)	9	0	0	0	0
Filterable Residue (mg/l)	4	4900	748	5900	4100
Oil & Grease (mg/l)	4	4	3	8	0
Ammonia (mg/l N)*	9	.06	.03	.13	.02
Nitrite (mg/l N)*	9	.01	.01	.03	.00
Nitrate (mg/l N)*	8	.49	.65	1.6	.00
Kjeldahl Nitrogen (mg/l N)	9	.81	.12	1.0	.63
NO_2 + NO_3 (mg/l N)*	9	.44	.62	1.6	.00
Orthophosphate (mg/l PO_4)*	9	.04	.03	.09	.00
Phosphorous (mg/l)	9	.08	.15	.48	.01
Orthophosphorous (mg/l P)*	9	.01	.01	.03	.00
Total Organic Carbon (mg/l)	2	22	1	22.0	21.0
Total Inorganic Carbon (mg/l)	1	90	-	-	-
Cyanide (mg/l)	5	0	0	.00	.00
Sulfide (mg/l)*	9	.1	.1	.3	.0
Hardness (mg/l Ca, Mg)	9	1400	112	1600	1300
Non Carbonate Hardness (mg/l)	9	923	102	1100	820
Calcium (mg/l)*	9	214	14	240	200
Magnesium (mg/l)*	9	209	25	250	170
Sodium (mg/l)*	9	972	71	1100	860
Sodium Adsorption Ratio	9	11	1	12.0	10.0
% Sodium	9	60	2	62	58
Potassium (mg/l)*	9	8	3	11.0	2.2
Chloride (mg/l)*	9	66	9	87	56
Sulfate (mg/l)*	9	2889	247	3300	2600
Fluoride (mg/l)*	9	.9	.1	1.1	.8
Silica (mg/l)*	9	10	1	11	8.8
Arsenic (mg/l)*	5	3	1	5	1
Barium (mg/l)*	5	<.1	-	<.1	-
Beryllium (mg/l)*	2	<.01	-	<.01	-
Bismuth (mg/l)*	1	<.09	-	<.09	-
Boron (mg/l)*	5	1.95	.95	2.7	.31
Cadmium (mg/l)*	5	<.001	-	<.001	-
Chromium (mg/l)*	5	<.012	-	.02	-
Cobalt (mg/l)*	5	<.003	-	.003	-
Copper (mg/l)*	5	.004	.002	.007	.003
Iron (mg/l)*	5	.026	.015	.050	.01
Lead (mg/l)*	5	<.002	-	<.002	-
Manganese (mg/l)*	5	.127	.061	.21	.067
Mercury (mg/l)*	5	<.00002	-	<.0001	
Molybdenum (mg/l)*	5	.036	.008	.045	.024
Nickel (mg/l)*	5	.011	.006	.018	.004
Silver (mg/l)*	2	<.001	-	.001	-
Strontium (mg/l)*	2	4.2	.14	4.3	4.1
Vanadium (mg/l)*	4	<.003	-	.0042	-
Zinc (mg/l)*	5	.014	.005	.020	.010
Tin (mg/l)*	1	<.09	-	<.09	-
Aluminum (mg/l)*	5	<.01	-	.01	-
Gallium (mg/l)*	1	<.04	-	<.04	-
Germanium (mg/l)*	1	<.09	-	<.09	-
Lithium (mg/l)*	5	.110	.010	.12	.10
Selenium (mg/l)*	5	<.003	-	.003	-
Titanium (mg/l)*	1	<.060	-	<.06	-
Zirconium (mg/l)*	1	<.15	-	<.15	-
Gross Beta (mg/l Cs_{137})*	4	.062	.072	.17	.020
Chlorophyll A (mg/l)	4	.0011	.0006	.0018	.0004
Chlorophyll B (mg/l)	4	.0015	.0012	.003	.000
Phenols (mg/l)	9	<.002	-	.007	-
Dissolved Solids (mg/l)*	9	4948	360	5620	4500
Gross Alpha (mg/l U)*	4	.09	-	<.02	-
Gross Beta (mg/l SR_{90}/Y_{90})*	4	.05	.06	.14	.018

* Elements analyzed only for dissolved fraction.

APPENDIX II-10

SUMMARY OF WATER QUALITY

EVACUATION CREEK NEAR MOUTH (S-2)

AUGUST 1974 THRU FEBRUARY 17, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (^{o}C)	11	11	11	31.0	.5
Turbidity (JTU)	6	1.7	1.2	4	1
Conductance (umhos)	10	4666	400	5500	1300
Chemical Oxygen Demand (mg/l)	11	24	8	35	6
pH (pH Units)	9	8.2	0.3	8.7	7.8
Carbon Dioxide (mg/l)	9	6.0	3.8	14.0	1.6
Alkalinity (mg/l $CACO_3$)	11	404	34	444	351
Bicarbonate (mg/l HCO_3)	11	493	42	541	428
Carbonate (mg/l CO_3)	11	0	0	0	0
Filterable Residue (mg/l)	5	4180	540	5000	3600
Oil & Grease (mg/l)	9	29	83	250	0
Ammonia (mg/l N)*	10	0.06	0.05	.11	.01
Nitrite (mg/l N)*	11	0.01	0.01	.03	.00
Nitrate (mg/l N)*	10	0.07	0.10	.32	.00
Kjeldahl Nitrogen (mg/l N)	11	0.68	0.27	1.2	.36
NO_2 + NO_3 (mg/l N)*	11	0.07	0.10	.34	.00
Orthophosphate (mg/l PO_4)*	11	0.03	0.03	.09	.00
Phosphorous (mg/l)	11	0.03	0.01	.05	.01
Orthophesphorous (mg/l P)*	11	0.01	0.01	.03	.00
Total Organic Carbon (mg/l)	2	12	1.4	13	11
Total Inorganic Carbon (mg/l)	1	43	---	---	---
Cyanide (mg/l)	6	0.00	0	.00	.00
Sulfide (mg/l)*	11	0.06	0.09	.3	.0
Hardness (mg/l Ca, Mg)	11	1120	75	1200	1000
Non Carbonate Hardness (mg/l)	11	700	43	760	650
Calcium (mg/l)*	11	172	16	200	140
Magnesium (mg/l)*	11	164	11	180	150
Sodium (mg/l)*	11	728	33	780	680
Sodium Adsorption Ratio	11	9.5	0.2	9.8	9.3
% Sodium	11	59	1	60	58
Potassium (mg/l)*	11	7.8	2.7	12.0	1.8
Chloride (mg/l)*	11	54	4	60	49
Sulfate (mg/l)*	11	2160	150	2400	2000
Fluoride (mg/l)*	11	0.8	0.1	.9	.6
Silica (mg/l)*	11	8.8	0.9	10	7.6
Arsenic (mg/l)*	7	.0028	.0015	<.006	.002
Barium (mg/l)*	7	<.1	---	<.1	---
Beryllium (mg/l)*	3	<.006	---	.006	---
Bismuth (mg/l)*	2	.040	---	.063	---
Boron (mg/l)*	7	2.17	.24	2.500	1.900
Cadmium (mg/l)*	7	0	---	0	---
Chromium (mg/l)*	7	<.01	---	.03	---
Cobalt (mg/l)*	7	<.001	---	.002	---
Copper (mg/l)*	7	.002	.001	.004	.001
Iron (mg/l)*	7	.029	.012	.05	.02
Lead (mg/l)*	7	.002	.001	.003	.000
Manganese (mg/l)*	7	.083	.054	.19	.03
Mercury (mg/l)*	7	<.0001	-	.0003	
Molybdenum (mg/l)*	7	.052	.009	.067	.037
Nickel (mg/l)*	7	.006	.003	.009	.002
Silver (mg/l)*	2	<.002	---	<.002	---
Strontium (mg/l)*	3	4.100	0.17	4.2	3.9
Vanadium (mg/l)*	7	.0013	.0013	.0032	.000
Zinc (mg/l)*	7	<.027	---	.06	---
Tin (mg/l)*	2	<.065	---	<.065	---
Aluminum (mg/l)*	7	.011	.012	.09	.00
Gallium (mg/l)*	2	<.03	---	.03	---
Germanium (mg/l)*	2	<.065	---	.065	---
Lithium (mg/l)*	7	.13	.01	.15	.05
Selenium (mg/l)*	6	.0008	.0008	.002	.00
Titanium (mg/l)*	2	<.045	---	<.045	---
Zirconium (mg/l)*	2	<.11	---	<.11	---
Gross Beta (mg/l Cs_{137})*	5	.029	.020	.066	.016
Chlorophyll A (mg/l)	5	.005	.005	.013	.000
Chlorophyll B (mg/l)	5	.003	.002	.0054	.005
Phenols (mg/l)	9	.005	.008	.025	.000
Dissolved Solids (mg/l)*	11	3826	159	4070	3290
Gross Alpha (mg/l U)*	5	<.009	---	.28	---
Gross Beta (mg/l SR_{90}/Y_{90})*	5	25	16	53	14

* Elements analyzed only for dissolved fraction.

APPENDIX II-11

SUMMARY OF WATER QUALITY
WHITE RIVER ABOVE HELLS HOLE CANYON (S-1)
May 6, 1975 thru August 5, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	7	15.6	4.9	21.0	8.5
Turbidity (JTU)	7	454	443	1200	46
Conductance (umhos)	7	505	106	800	365
Chemical Oxygen Demand (mg/l)	7	56	50	140	13
pH (pH Units)	6	8.3	0.2	8.6	8.0
Carbon Dioxide (mg/l)	6	1.5	0.6	2.3	0.6
Alkalinity (mg/l $CACO_3$)	7	143	29	193	119
Bicarbonate (mg/l HCO_3)	7	175	35	235	145
Carbonate (mg/l CO_3)	6	0.17	0.41	1	0
Filterable Residue (mg/l)	3	347	148	510	220
Oil & Grease (mg/l)	7	2.0	3.2	9	0
Ammonia (mg/l N)*	7	0.02	0.02	0.04	0.00
Nitrite (mg/l N)*	7	0.004	0.005	0.01	0.00
Nitrate (mg/l N)*	7	0.12	0.12	0.36	0.01
Kjeldahl Nitrogen (mg/l N)	7	2.6	1.9	4.9	0.41
NO_2 + NO_3 (mg/l N)*	7	0.12	0.12	0.36	0.01
Orthophosphate (mg/l PO_4)*	7	0.06	0.03	0.09	0.03
Phosphorous (mg/l)	7	0.25	0.15	0.46	0.01
Orthophosphorous (mg/l P)*	7	0.02	0.01	0.03	0.01
Total Organic Carbon (mg/l)	1	39	-	39	-
Total Inorganic Carbon (mg/l)	-	-	-	-	-
Cyanide (mg/l)	4	0	0	0	-
Sulfide (mg/l)*	7	0.06	0.05	0.1	0.0
Hardness (mg/l Ca, Mg)	7	194	52	270	150
Non Carbonate Hardness (mg/l)	7	52	24	91	29
Calcium (mg/l)*	7	49	11	63	38
Magnesium (mg/l)*	7	18	6	27	13
Sodium (mg/l)*	7	35	18	66	21
Sodium Adsorption Ratio	7	1.1	0.4	1.8	0.7
% Sodium	7	27	5	35	21
Potassium (mg/l)*	7	1.7	0.3	2.0	1.3
Chloride (mg/l)*	7	17	11	37.0	8.3
Sulfate (mg/l)*	7	98	44	170	59
Fluoride (mg/l)*	7	0.21	0.04	0.3	0.2
Bromide (mg/l)	7	0.0	0.0	0.1	0.0
Silica (mg/l)*	7	13	1.3	15	11
Arsenic (mg/l)*	4	0.001	0.0008	0.002	0.000
Barium (mg/l)*	5	0.074	0.069	0.140	0.000
Beryllium (mg/l)*	3	<0.00033	-	<0.001	-
Bismuth (mg/l)*	2	<0.004	-	<0.006	-
Boron (mg/l)*	5	0.043	0.011	0.060	0.030
Cadmium (mg/l)*	5	<0.0008	-	<0.004	-
Chromium (mg/l)*	5	<0.002	0.0035	0.008	0.000
Cobalt (mg/l)*	5	<0.001	0.001	0.002	0.000
Copper (mg/l)*	5	0.0034	0.0019	0.006	0.002
Iron (mg/l)*	5	-	0.032	0.060	0.00
Lead (mg/l)*	5	<0.0014	0.0017	0.004	0.000
Manganese (mg/l)*	5	0.019	0.035	0.082	0.00
Mercury (mg/l)*	4	0.00003	0.0005	0.0001	0.0000
Molybdenum (mg/l)*	5	0.0032	0.0019	0.006	0.001
Nickel (mg/l)*	5	0.0042	0.0048	0.012	0.000
Silver (mg/l)*	3	0.000	-	0.000	0.000
Strontium (mg/l)*	3	0.493	0.162	0.680	0.390
Vanadium (mg/l)*	5	0.0032	0.0063	0.010	0.0008
Zinc (mg/l)*	5	0.012	0.011	0.030	0.000
Tin (mg/l)*	2	<0.004	-	<0.006	-
Aluminum (mg/l)*	5	<1.224	2.67	6.00	<0.010
Gallium (mg/l)*	2	<0.001	-	<0.002	-
Germanium (mg/l)*	2	<0.003	-	<0.004	<0.002
Lithium (mg/l)*	5	0.009	0.0010	0.0020	0.00
Selenium (mg/l)*	4	0.0013	0.0005	0.002	0.001
Titanium (mg/l)*	2	0.304	0.419	0.600	0.007
Zirconium (mg/l)*	2	0.0017	0.0019	0.030	<0.003
Gross Beta (pc/l Cs_{137})*	3	4.8	1.9	6.9	3.4
Chlorophyll A (mg/l)	3	0.0057	0.0064	0.013	0.0009
Chlorophyll B (mg/l)	3	0.0019	0.0005	0.0023	0.0013
Phenols (mg/l)	7	0.0044	0.0021	0.009	0.002
Dissolved Solids (mg/l)*	7	324	107	484	226
Gross Alpha (mg/l U)*	3	0.0069	0.0027	0.0085	0.0027
Gross Beta (pc/l SR_{90}/Y_{90})*	3	3.8	1.6	5.6	2.7

*Elements analyzed only for dissolved fraction

APPENDIX II-12

SUMMARY OF WATER QUALITY
WHITE RIVER NEAR WATSON UTAH (S-3)
May 5, 1975 thru August 4, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	7	16.3	4.6	22.0	10.5
Turbidity (JTU)	6	389	283	800	76
Conductance (umhos)	7	533	165	760	330
Chemical Oxygen Demand (mg/l)	6	40	23	81	19
pH (pH Units)	7	8.4	0.8	10.1	7.4
Carbon Dioxide (mg/l)	7	2.8	3.4	10	0.0
Alkalinity (mg/l $CACO_3$)	7	145	31	196	107
Bicarbonate (mg/l HCO_3)	7	154	77	239	131
Carbonate (mg/l CO_3)	7	0	-	0	0
Filterable Residue (mg/l)	3	360	115	490	270
Oil & Grease (mg/l)	6	1.3	0.5	2	1
Ammonia (mg/l N)*	6	0.03	0.05	0.13	0.00
Nitrite (mg/l N)*	6	0.002	0.004	0.01	0.00
Nitrate (mg/l N)*	6	0.11	0.12	0.33	0.01
Kjeldahl Nitrogen (mg/l N)	6	1.9	1.1	3.3	0.86
NO_2 + NO_3 (mg/l N)*	7	0.10	0.11	0.33	0.01
Orthophosphate (mg/l PO_4)*	7	30	79	210	0.00
Phosphorous (mg/l)	6	0.38	0.41	1.1	0.01
Orthophosphorous (mg/l P)*	7	9.7	26	68	0.01
Total Organic Carbon (mg/l)	1	14	-	14	-
Total Inorganic Carbon (mg/l)	0	-	-	-	-
Cyanide (mg/l)	3	0.00	0.00	0.00	0.00
Sulfide (mg/l)*	5	0.06	0.05	0.1	0.0
Hardness (mg/l Ca, Mg)	7	200	51	270	140
Non Carbonate Hardness (mg/l)	7	55	24	97	29
Calcium (mg/l)*	7	50	12	67	35
Magnesium (mg/l)*	7	18	6	27	12
Sodium (mg/l)*	7	35	18	60	17
Sodium Adsorption Ratio	7	1.0	0.4	1.7	0.6
% Sodium	7	26	5	34	18
Potassium (mg/l)*	7	1.7	0.4	2.2	1.2
Chloride (mg/l)*	7	17	9.6	35	8.9
Sulfate (mg/l)*	7	100	46	180	59
Fluoride (mg/l)*	7	0.21	0.04	0.3	0.2
Bromide (mg/l)	5	0.0	0.1	0.4	0.0
Silica (mg/l)*	7	11	4.7	15	1.0
Arsenic (mg/l)*	3	0.0010	0.0010	.002	0.001
Barium (mg/l)*	4	0.058	0.068	.130	0.000
Beryllium (mg/l)*	2	0.000	-	0.000	-
Bismuth (mg/l)*	1	0.002	-	<0.002	-
Boron (mg/l)*	5	0.051	0.025	0.090	0.025
Cadmium (mg/l)*	4	0.0008	-	<0.003	-
Chromium (mg/l)*	4	0.0005	-	<0.002	-
Cobalt (mg/l)*	4	<0.00075	-	<0.002	-
Copper (mg/l)*	4	0.0025	0.0022	0.005	0.001
Iron (mg/l)*	4	0.040	0.023	0.060	0.020
Lead (mg/l)*	4	<0.0005	0.0010	<0.002	0.000
Manganese (mg/l)*	4	0.0010	0.0020	0.004	0.00
Mercury (mg/l)*	3	0.000	0.0000	0.0000	0.0000
Molybdenum (mg/l)*	4	0.0023	0.0010	0.003	0.001
Nickel (mg/l)*	4	0.0033	0.0017	0.005	0.001
Silver (mg/l)*	2	0.000	0.000	0.000	0.000
Strontium (mg/l)*	2	0.210	0.212	0.360	0.060
Vanadium (mg/l)*	4	0.0016	0.0009	0.0025	0.0004
Zinc (mg/l)*	4	0.0093	0.011	0.020	0.00
Tin (mg/l)*	1	<0.002	-	<0.002	-
Aluminum (mg/l)*	4	0.040	0.034	0.090	0.020
Gallium (mg/l)*	1	0	-	0	-
Germanium (mg/l)*	1	<0.002	-	<0.002	-
Lithium (mg/l)*	4	0.0063	0.0095	0.020	0.00
Selenium (mg/l)*	3	0.0007	0.0006	0.001	0.000
Titanium (mg/l)*	1	0.006	-	0.006	-
Zirconium (mg/l)*	1	<0.003	-	<0.003	-
Gross Beta (pc/l Cs_{137})*	3	4.8	1.1	6.0	4.1
Chlorophyll A (mg/l)	3	0.0030	0.0021	0.0054	0.0018
Chlorophyll B (mg/l)	3	0.0026	0.0012	0.0035	0.0012
Phenols (mg/l)	5	0.0048	0.0008	0.006	0.004
Dissolved Solids (mg/l)*	6	310	90	462	223
Gross Alpha (mg/l U)*	3	<0.0078	0.0030	0.010	<0.0043
Gross Beta (pc/l Sr_{90}/Y_{90})*	3	3.8	0.9	4.9	3.2

*Elements analyzed only for dissolved fraction

APPENDIX II-13

SUMMARY OF WATER QUALITY
WHITE RIVER ABOVE SOUTHAM CANYON (S-4)
May 6, 1975 thru August 6, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	7	15.8	5.5	22.0	7.9
Turbidity (JTU)	7	896	880	2000	60
Conductance (umhos)	7	506	174	810	360
Chemical Oxygen Demand (mg/l)	7	80	71	200	17
pH (pH Units)	6	8.1	0.5	8.8	7.2
Carbon Dioxide (mg/l)	6	4.3	6.2	17	0.4
Alkalinity (mg/l $CACO_3$)	7	145	27	193	126
Bicarbonate (mg/l HCO_3)	7	176	33	235	153
Carbonate (mg/l CO_3)	7	0	0	0	0
Filterable Residue (mg/l)	4	418	131	560	270
Oil & Grease (mg/l)	7	2.1	1.6	5	0
Ammonia (mg/l N)*	7	0.026	0.022	0.06	0.00
Nitrite (mg/l N)*	7	0.013	0.011	0.03	0.00
Nitrate (mg/l N)*	7	0.12	0.11	0.32	0.01
Kjeldahl Nitrogen (mg/l N)	7	2.6	2.6	7.6	0.47
NO_2 + NO_3 (mg/l N)*	7	0.14	0.10	0.32	0.01
Orthophosphate (mg/l PO_4)*	7	0.07	0.06	0.18	0.00
Phosphorous (mg/l)	7	0.98	0.68	1.9	0.19
Orthophosphorous (mg/l P)*	7	0.022	0.021	0.06	0.00
Total Organic Carbon (mg/l)	1	48	-	48	-
Total Inorganic Carbon (mg/l)	0	-	-	-	-
Cyanide (mg/l)	4	0.003	0.005	0.01	0.00
Sulfide (mg/l)*	7	0.07	0.10	0.2	0.0
Hardness (mg/l Ca, Mg)	7	199	49	280	160
Non Carbonate Hardness (mg/l)	7	52	25	100	26
Calcium (mg/l)*	7	49	11	64	40
Magnesium (mg/l)*	7	18	5	28	14
Sodium (mg/l)*	7	40	19	75	21
Sodium Adsorption Ratio	7	1.2	0.4	2.0	0.7
% Sodium	7	29	5	37	21
Potassium (mg/l)*	7	1.9	0.4	2.4	1.3
Chloride (mg/l)*	7	18	12	42	8.6
Sulfate (mg/l)*	7	106	46	190	66
Fluoride (mg/l)*	7	0.24	0.05	0.3	0.2
Bromide (mg/l)	7	0.0	0.1	0.1	0.0
Silica (mg/l)*	7	13	2	17	11
Arsenic (mg/l)*	4	0.001	.0008	0.002	0.000
Barium (mg/l)*	5	0.053	.050	0.1	0.0
Beryllium (mg/l)*	2	0	0	0	0.000
Bismuth (mg/l)*	1	0.002	-	0.002	-
Boron (mg/l)*	5	0.056	.023	0.090	.040
Cadmium (mg/l)*	5	<0.0012	-	<0.004	-
Chromium (mg/l)*	5	<0.0004	-	<0.002	-
Cobalt (mg/l)*	5	<0.0006	-	<0.002	-
Copper (mg/l)*	5	0.0054	0.0035	0.011	0.002
Iron (mg/l)*	5	0.062	0.048	0.13	0.01
Lead (mg/l)*	5	<0.0022	0.0022	0.005	0.000
Manganese (mg/l)*	5	0.0016	0.0023	0.005	0.00
Mercury (mg/l)*	4	0.00005	0.0001	0.0002	0.0000
Molybdenum (mg/l)*	5	0.0026	0.0013	0.004	0.001
Nickel (mg/l)*	5	0.0038	0.0023	0.006	0.001
Silver (mg/l)*	2	0.000	0.000	0.000	0.000
Strontium (mg/l)*	2	0.505	0.120	0.590	0.420
Vanadium (mg/l)*	5	0.0019	0.0009	0.0030	0.0004
Zinc (mg/l)*	5	0.0074	0.0083	0.020	0
Tin (mg/l)*	1	<0.002	-	<0.002	-
Aluminum (mg/l)*	5	0.072	0.075	0.200	0.020
Gallium (mg/l)*	1	0	-	0	-
Germanium (mg/l)*	1	<0.002	-	<0.002	-
Lithium (mg/l)*	5	0.0054	0.0087	0.020	0.000
Selenium (mg/l)*	4	0.0006	0.0009	0.002	0.000
Titanium (mg/l)*	1	0.010	-	0.010	-
Zirconium (mg/l)*	1	<0.003	-	<0.003	-
Gross Beta (pc/l Cs_{137})*	4	3.5	0.5	4.1	2.8
Chlorophyll A (mg/l)	2	0.0095	0.0022	0.011	0.0079
Chlorophyll B (mg/l)	2	0.0076	0.0025	0.011	0.0079
Phenols (mg/l)	7	0.006	0.0041	0.014	0.002
Dissolved Solids (mg/l)*	7	342	114	536	245
Gross Alpha (mg/l U)*	4	<0.0065	0.0039	0.012	<0.0038
Gross Beta (pc/l SR_{90}/Y_{90})*	4	2.9	0.5	3.4	2.3

*Elements analyzed only for dissolved fraction

APPENDIX II-14

SUMMARY OF WATER QUALITY
WHITE RIVER BELOW ASPHALT WASH (S-11)
May 15, 1975 thru August 7, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	7	17.1	3.9	21.0	10.1
Turbidity (JTU)	6	323	269	760	56
Conductance (umhos)	6	480	157	710	320
Chemical Oxygen Demand (mg/l)	6	23	11	40	8
pH (pH Units)	4	7.9	0.3	8.3	7.6
Carbon Dioxide (mg/l)	4	4.1	2.8	8.2	1.9
Alkalinity (mg/l $CACO_3$)	6	141	32	191	123
Bicarbonate (mg/l HCO_3)	6	172	39	233	125
Carbonate (mg/l CO_3)	6	0	0	0	0
Filterable Residue (mg/l)	2	360	127	450	270
Oil & Grease (mg/l)	6	1.7	1.8	5	0
Ammonia (mg/l N)*	6	0.011	0.015	0.03	0.00
Nitrite (mg/l N)*	6	0.010	0.011	0.03	0.00
Nitrate (mg/l N)*	6	0.14	0.13	0.38	0.01
Kjeldahl Nitrogen (mg/l N)	6	1.2	0.8	2.5	0.45
NO_2 + NO_3 (mg/l N)*	6	0.15	0.13	0.39	0.02
Orthophosphate (mg/l PO_4)*	6	0.04	0.04	0.12	0.00
Phosphorous (mg/l)	6	0.29	0.21	0.61	0.05
Orthophosphorous (mg/l P)*	6	0.013	0.014	0.04	0.00
Total Organic Carbon (mg/l)	1	8.8	-	8.8	-
Total Inorganic Carbon (mg/l)	0	-	-	-	-
Cyanide (mg/l)	4	0.003	0.005	0.01	0.00
Sulfide (mg/l)*	6	0.07	0.08	0.2	0.0
Hardness (mg/l Ca, Mg)	6	192	49	270	140
Non Carbonate Hardness (mg/l)	6	50	54	77	31
Calcium (mg/l)*	6	48	11	66	41
Magnesium (mg/l)*	6	17	5	25	11
Sodium (mg/l)*	6	35	14	55	22
Sodium Adsorption Ratio	6	1.1	0.3	1.5	0.8
% Sodium	6	28	3	32	24
Potassium (mg/l)*	6	1.8	0.4	2.3	1.3
Chloride (mg/l)*	6	15	8	27	9.3
Sulfate (mg/l)*	6	101	34	150	63
Fluoride (mg/l)*	6	0.22	0.04	0.3	0.2
Bromide (mg/l)	7	0.0	0.1	0.1	0.0
Silica (mg/l)*	6	13	2	15	11
Arsenic (mg/l)*	4	0.0015	0.001	0.002	0.000
Barium (mg/l)*	4	<0.025	-	<0.100	-
Beryllium (mg/l)*	1	0.000	-	0.000	-
Bismuth (mg/l)*	0	-	-	-	-
Boron (mg/l)*	4	0.053	0.025	0.080	0.020
Cadmium (mg/l)*	4	0.0005	0.001	0.002	0.000
Chromium (mg/l)*	4	0.0025	0.005	0.010	0.000
Cobalt (mg/l)*	4	0.00025	0.0005	0.001	0.000
Copper (mg/l)*	4	0.0055	0.0051	0.013	0.002
Iron (mg/l)*	4	0.045	0.021	0.07	0.02
Lead (mg/l)*	4	0.0013	0.0015	0.003	0.000
Manganese (mg/l)*	4	0.0025	0.005	0.01	0.00
Mercury (mg/l)*	4	0.0000	0.0000	0.0000	0.0000
Molybdenum (mg/l)*	4	0.0020	0.0008	0.003	0.001
Nickel (mg/l)*	4	0.0035	0.0021	0.006	0.006
Silver (mg/l)*	1	0.000	-	0.000	-
Strontium (mg/l)*	1	0.060	-	0.060	-
Vanadium (mg/l)*	4	0.001	0.0011	0.0024	0.0000
Zinc (mg/l)*	4	0.0015	0.003	0.006	0.000
Tin (mg/l)*	0	-	-	-	-
Aluminum (mg/l)*	4	0.035	0.010	0.050	0.030
Gallium (mg/l)*	0	-	-	-	-
Germanium (mg/l)*	0	-	-	-	-
Lithium (mg/l)*	4	0.0075	0.0096	0.020	0.000
Selenium (mg/l)*	4	0.0008	0.0005	0.001	0.000
Titanium (mg/l)*	0	-	-	-	-
Zirconium (mg/l)*	0	-	-	-	-
Gross Beta (pc/l Cs_{137})*	2	3.85	0.07	3.9	3.8
Chlorophyll A (mg/l)	4	0.0059	0.0051	0.013	0.002
Chlorophyll B (mg/l)	4	0.0053	0.0043	0.0099	0.0002
Phenols (mg/l)	6	0.0043	0.0042	0.007	0.002
Dissolved Solids (mg/l)*	6	326	93	467	223
Gross Alpha (mg/l U)*	2	0.0064	0.0037	0.0090	0.0038
Gross Beta (pc/l SR_{90}/Y_{90})*	2	3.3	0.1	3.4	3.2

*Elements analyzed only for dissolved fraction

APPENDIX II-15

SUMMARY OF WATER QUALITY
EVACUATION CREEK BELOW PARK CANYON (S-7)
March 5, 1975 thru August 6, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	10	15.1	9.9	31.4	0.0
Turbidity (JTU)	10	1123	1341	3600	12
Conductance (umhos)	10	3877	544	2900	4540
Chemical Oxygen Demand (mg/l)	10	61	77	270	13
pH (pH Units)	8	8.3	0.2	8.7	8.1
Carbon Dioxide (mg/l)	8	3.9	1.6	6.0	1.5
Alkalinity (mg/l $CACO_3$)	10	375	16	390	346
Bicarbonate (mg/l HCO_3)	10	457	19	475	422
Carbonate (mg/l CO_3)	10	0	0	0	0
Filterable Residue (mg/l)	6	3883	1063	5600	3000
Oil & Grease (mg/l)	10	1.9	1.4	5	0
Ammonia (mg/l N)*	10	0.02	0.01	0.04	0.00
Nitrite (mg/l N)*	10	0.014	0.010	0.03	0.00
Nitrate (mg/l N)*	10	1.9	1.7	5.0	0.70
Kjeldahl Nitrogen (mg/l N)	10	4.1	7.5	25	0.47
NO_2 + NO_3 (mg/l N)*	10	1.9	1.7	5.0	0.20
Orthophosphate (mg/l PO_4)*	10	0.05	0.03	0.12	0.00
Phosphorous (mg/l)	10	0.85	1.4	4.8	0.00
Orthophosphorous (mg/l P)*	10	0.017	0.012	0.04	0.00
Total Organic Carbon (mg/l)	2	4.8	3.0	6.9	2.6
Total Inorganic Carbon (mg/l)	0	-	-	-	-
Cyanide (mg/l)	6	0.002	0.004	0.01	0.00
Sulfide (mg/l)*	10	0.005	0.007	0.2	0.0
Hardness (mg/l Ca, Mg)	10	963	118	1100	730
Non Carbonate Hardness (mg/l)	10	589	120	750	380
Calcium (mg/l)*	10	137	18	160	120
Magnesium (mg/l)*	10	151	20	180	110
Sodium (mg/l)*	10	658	83	790	490
Sodium Adsorption Ratio	10	9.2	0.7	10.0	7.9
% Sodium	10	60	1.7	62	56
Potassium (mg/l)*	10	6.5	1.6	8.8	4.9
Chloride (mg/l)*	10	31	6	43	23
Sulfate (mg/l)*	10	1920	282	2400	1400
Fluoride (mg/l)*	10	0.66	0.16	0.9	0.4
Bromide (mg/l)	9	0.2	0.1	0.5	0.2
Silica (mg/l)*	10	11	2	15	9.5
Arsenic (mg/l)*	6	0.0012	0.0008	0.002	0.0
Barium (mg/l)*	7	<0.123	0.140	0.400	0.0
Beryllium (mg/l)*	3	0.005	0.005	0.010	0.0
Bismuth (mg/l)*	1	<0.015	-	<0.015	-
Boron (mg/l)*	7	0.482	0.304	1.100	0.220
Cadmium (mg/l)*	7	0.000	0.000	0.000	0.000
Chromium (mg/l)*	7	<0.0021	-	<0.0015	-
Cobalt (mg/l)*	7	<0.0024	-	<0.0015	-
Copper (mg/l)*	7	0.0054	0.0029	0.010	0.003
Iron (mg/l)*	7	0.050	0.043	0.120	0.01
Lead (mg/l)*	7	0.0026	0.0055	0.015	0.000
Manganese (mg/l)*		0.030	0.016	0.06	0.01
Mercury (mg/l)*	6	0.000017	0.00004	0.0001	0.0000
Molybdenum (mg/l)*	7	<0.024	0.010	0.042	0.013
Nickel (mg/l)*	7	<0.0047	-	<0.015	-
Silver (mg/l)*	3	<0.001	-	<0.002	-
Strontium (mg/l)*	3	3.366	0.306	3.700	3.100
Vanadium (mg/l)*	7	<0.0026	-	<0.015	-
Zinc (mg/l)*	7	0.0089	0.010	0.020	0.00
Tin (mg/l)*	1	<0.015	-	<0.015	-
Aluminum (mg/l)*	7	0.040	0.042	0.130	0.010
Gallium (mg/l)*	1	<0.007	-	<0.007	-
Germanium (mg/l)*	1	<0.020	-	<0.020	-
Lithium (mg/l)*	7	0.067	0.015	0.090	0.050
Selenium (mg/l)*	6	0.0025	0.001	0.004	0.001
Titanium (mg/l)*	1	<0.015	-	<0.015	-
Zirconium (mg/l)*	1	<0.030	-	<0.030	-
Gross Beta (pc/l Cs_{137})*	6	6	4.9	30	<17
Chlorophyll A (mg/l)	4	0.0024	0.0021	5.2	0.8
Chlorophyll B (mg/l)	4	0.0016	0.0017	0.0039	0.0000
Phenols (mg/l)	10	0.0070	0.0043	0.014	0.001
Dissolved Solids (mg/l)*	10	3260	457	4040	2460
Gross Alpha (mg/l U)*	6	<0.064	0.024	0.100	<0.038
Gross Beta (pc/l SR_{90}/Y_{90})*	6	<17	4.4	25	<13

*Elements analyzed only for dissolved fraction

APPENDIX II-16

SUMMARY OF WATER QUALITY
EVACUATION CREEK AT WATSON (S-6)
March 4, 1975 thru August 4, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	10	15.2	9.7	28.2	0.8
Turbidity (JTU)	10	1432	2118	6800	26
Conductance (umhos)	10	4116	1002	5140	1650
Chemical Oxygen Demand (mg/l)	10	77	92	330	32
pH (pH Units)	8	8.3	0.3	8.8	7.9
Carbon Dioxide (mg/l)	8	4.0	3.1	11	1.1
Alkalinity (mg/l $CACO_3$)	10	334	105	459	128
Bicarbonate (mg/l HCO_3)	10	399	145	559	129
Carbonate (mg/l CO_3)	10	4.2	13	42	0
Filterable Residue (mg/l)	5	3180	1221	4200	1300
Oil & Grease (mg/l)	9	8.0	17	52	1
Ammonia (mg/l N)*	10	0.018	0.015	0.04	0.00
Nitrite (mg/l N)*	10	0.012	0.016	0.05	0.00
Nitrate (mg/l N)*	10	1.3	0.6	2.2	0.06
Kjeldahl Nitrogen (mg/l N)	10	2.1	2.1	7.9	0.96
NO_2 + NO_3 (mg/l N)*	10	1.3	0.6	2.2	0.09
Orthophosphate (mg/l PO_4)*	10	0.05	0.05	0.12	0.00
Phosphorous (mg/l)	10	1.2	1.6	4.7	0.01
Orthophosphorous (mg/l P)*	10	0.017	0.017	0.04	0.00
Total Organic Carbon (mg/l)	2	21	18	34	8.2
Total Inorganic Carbon (mg/l)	0	-	-	-	-
Cyanide (mg/l)	6	0.007	0.004	0.02	0.00
Sulfide (mg/l)*	10	0.08	0.10	0.3	0.0
Hardness (mg/l Ca, Mg)	10	992	272	1400	340
Non Carbonate Hardness (mg/l)	10	656	181	910	220
Calcium (mg/l)*	10	140	34	200	73
Magnesium (mg/l)*	10	155	46	210	39
Sodium (mg/l)*	10	676	196	980	230
Sodium Adsorption Ratio	10	9.2	1.7	12	5.4
% Sodium	10	59.5	1.7	61	56
Potassium (mg/l)*	10	7.1	2.0	12	5.4
Chloride (mg/l)*	10	39	11	63	18
Sulfate (mg/l)*	10	1998	599	3000	680
Fluoride (mg/l)*	10	0.8	0.2	1.0	0.5
Bromide (mg/l)	10	0.3	0.1	0.4	0.2
Silica (mg/l)*	10	10.6	3.5	17	6.3
Arsenic (mg/l)*	6	0.0017	0.001	0.003	0.000
Barium (mg/l)*	8	<0.057	-	<0.100	-
Beryllium (mg/l)*	5	<0.048	0.0039	0.010	0.0
Bismuth (mg/l)*	3	0.023	-	<0.040	-
Boron (mg/l)*	8	0.939	0.753	2.600	0.210
Cadmium (mg/l)*	8	0	0	0	0.000
Chromium (mg/l)*	8	<0.0046	-	<0.020	-
Cobalt (mg/l)*	8	<0.0031	-	<0.020	-
Copper (mg/l)*	8	0.007	0.0033	0.012	0.003
Iron (mg/l)*	8	0.080	0.068	0.22	0.02
Lead (mg/l)*	8	<0.0038	-	<0.020	-
Manganese (mg/l)*	8	<0.024	0.032	0.10	0.00
Mercury (mg/l)*	6	0	0	0	0.0000
Molybdenum (mg/l)*	8	0.027	0.010	0.043	0.019
Nickel (mg/l)*	8	<0.0049	0.0065	0.020	0.000
Silver (mg/l)*	5	<0.001	0.0014	0.003	0.000
Strontium (mg/l)*	5	2.800	1.433	4.200	1.200
Vanadium (mg/l)*	8	<0.0041	-	<0.020	-
Zinc (mg/l)*	8	0.013	0.013	0.040	0.010
Tin (mg/l)*	3	<0.023	-	<0.040	-
Aluminum (mg/l)*	8	0.047	0.046	0.130	0.010
Gallium (mg/l)*	3	<0.0073	-	<0.010	-
Germanium (mg/l)*	3	<0.021	-	<0.030	-
Lithium (mg/l)*	8	0.067	0.033	0.120	0.020
Selenium (mg/l)*	6	0.0025	0.0015	0.004	0.000
Titanium (mg/l)*	3	<0.018	0.014	0.030	<0.003
Zirconium (mg/l)*	3	<0.033	0.021	<0.050	<0.010
Gross Beta (pc/l Cs_{137})*	5	<19	4	26	<7
Chlorophyll A (mg/l)	5	0.005	0.008	0.019	0.0000
Chlorophyll B (mg/l)	5	0.0017	0.0018	0.004	0.0000
Phenols (mg/l)	10	0.0054	0.0066	0.024	0.001
Dissolved Solids (mg/l)*	10	3438	981	4920	1170
Gross Alpha (mg/l U)*	5	< 0.043	0.010	0.067	0.016
Gross Beta (pc/l SR_{90}/Y_{90})*	5	<17	3	20	<14

*Elements analyzed only for dissolved fraction

APPENDIX II-17

SUMMARY OF WATER QUALITY
EVACUATION CREEK NEAR MOUTH (S-2)
March 4, 1975 thru August 4, 1975

	Number Of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (^{o}C)	10	15.6	8.6	30	5.2
Turbidity (JTU)	10	777	1084	2800	3
Conductance (umhos)	10	4014	556	4800	2800
Chemical Oxygen Demand (mg/l)	10	47	30	110	22
pH (pH Units)	7	7.9	0.2	8.2	7.5
Carbon Dioxide (mg/l)	7	10	7.0	24	3.8
Alkalinity (mg/l $CACO_3$)	10	366	57	438	247
Bicarbonate (mg/l HCO_3)	10	447	70	534	301
Carbonate (mg/l CO_3)	9	0	0	0	0
Filterable Residue (mg/l)	5	3140	684	3800	2200
Oil & Grease (mg/l)	10	2.7	2.5	9	0
Ammonia (mg/l N)*	10	0.04	0.03	0.10	0.01
Nitrite (mg/l N)*	10	0.03	0.03	0.11	0.00
Nitrate (mg/l N)*	10	1.3	0.3	1.8	0.92
Kjeldahl Nitrogen (mg/l N)	10	1.4	1.4	5.0	0.39
NO_2 + NO_3 (mg/l N)*	10	1.3	0.3	1.8	0.96
Orthophosphate (mg/l PO_4)*	10	0.05	0.03	0.12	0.00
Phosphorous (mg/l)	10	0.17	0.18	0.52	0.00
Orthophosphorous (mg/l P)*	10	0.02	0.01	0.04	0.00
Total Organic Carbon (mg/l)	2	8.1	0.07	8.2	8.1
Total Inorganic Carbon (mg/l)	0	-	-	-	-
Cyanide (mg/l)	6	0.003	0.005	0.01	0.00
Sulfide (mg/l)*	10	0.06	0.07	0.2	0.0
Hardness (mg/l Ca, Mg)	10	1046	140	1200	690
Non Carbonate Hardness (mg/l)	10	669	90	770	440
Calcium (mg/l)*	10	157	24	190	110
Magnesium (mg/l)*	10	156	22	180	100
Sodium (mg/l)*	10	666	95	730	420
Sodium Adsorption Ratio	10	9.0	0.9	10	7.0
% Sodium	10	58	1.8	61	55
Potassium (mg/l)*	10	8.1	1.2	10	6.2
Chloride (mg/l)*	10	43	7	48	25
Sulfate (mg/l)*	10	1990	300	2200	1200
Fluoride (mg/l)*	10	0.77	0.11	0.9	0.5
Bromide (mg/l)	10	0.3	0.1	0.4	0.2
Silica (mg/l)*	10	10	2	14	6.1
Arsenic (mg/l)*	6	0.0008	0.0006	0.002	0.000
Barium (mg/l)*	6	<0.050	0.055	0.1	0.0
Beryllium (mg/l)*	2	<0.0050	0.0071	0.010	0.000
Bismuth (mg/l)*	0	-	-	-	-
Boron (mg/l)*	6	1.263	0.422	1.700	0.590
Cadmium (mg/l)*	6	0.00033	0.00052	0.001	0.000
Chromium (mg/l)*	6	0.000	0.000	0.000	0.000
Cobalt (mg/l)*	6	0.00033	0.00082	0.002	0.000
Copper (mg/l)*	6	0.132	0.237	0.600	0.006
Iron (mg/l)*	6	0.072	0.073	0.20	0.01
Lead (mg/l)*	6	0.0015	0.0016	0.004	0.000
Manganese (mg/l)*	6	0.045	0.024	0.09	0.02
Mercury (mg/l)*	6	0.00003	0.00008	0.0002	0.0000
Molybdenum (mg/l)*	6	0.034	0.009	0.044	0.020
Nickel (mg/l)*	6	0.0033	0.0023	0.006	0.000
Silver (mg/l)*	2	0.000	0.000	0.000	0.000
Strontium (mg/l)*	2	3.750	0.071	3.800	3.700
Vanadium (mg/l)*	6	0.00045	0.00054	0.0013	0.0000
Zinc (mg/l)*	6	0.027	0.025	0.070	0.00
Tin (mg/l)*	0	--	-	-	-
Aluminum (mg/l)*	6	0.053	0.049	0.110	0.000
Gallium (mg/l)*	0	-	-	-	-
Germanium (mg/l)*	0	-	-	-	--
Lithium (mg/l)*	6	0.093	0.025	0.120	0.050
Selenium (mg/l)*	6	0.0028	0.0010	0.004	0.002
Titanium (mg/l)*	0	-	-	-	-
Zirconium (mg/l)*	0	-	-	-	-
Gross Beta (pC/l Cs_{137})*	5	<20	7.5	29	<9.5
Chlorophyll A (mg/l)	5	0.0058	0.0076	0.018	0.0000
Chlorophyll B (mg/l)	5	0.0033	0.0041	0.010	0.0002
Phenols (mg/l)	10	0.0036	0.0024	0.008	0.001
Dissolved Solids (mg/l)*	10	3476	493	3820	2150
Gross Alpha (mg/l U)*	5	<0.057	0.033	0.110	<0.023
Gross Beta (pC/l SR_{90}/Y_{90})*	5	<16	6.2	23	<7.5

*Elements analyzed only for dissolved fraction

APPENDIX II-18

SUMMARY OF SURFACE WATER QUALITY
WHITE RIVER ABV. HELLS HOLE CYN. NR. WATSON (S-1)
BASE FLOW - AUG. 5, 1975 - OCT. 21, 1975

Description	Number of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	5	15.8	6.3	21.0	6.5
Turbidity (JTV)	5	25.	25.	54.	1.
Conductance (mhas)	5	719.	36.	762.	675.
Chemical Oxygen Demand (mg/1)	5	12.	5.	17.	5.
pH (pH Units)	4	8.5	0.1	8.6	8.4
Carbon Dioxide (mg/1)	4	1.2	0.3	1.5	0.9
Alkalinity (mg/1 $CACO_3$)	5	178.	19.	194.	147.
Bicarbonate (mg/1 HCO_3)	5	214.	23.	235.	175.
Carbonate (mg/1 CO_3)	5	2.	3.	7.	0.
Filterable Residue (mg/1)	1	560.	-------	560.	-------
Oil & Grease (mg/1)	5	0.	0.	0.	0.
Ammonia (mg/1 N)*	5	0.00	0.00	0.00	0.00
Nitrite (mg/1 N)*	5	0.002	0.004	0.01	0.00
Nitrate (mg/1 N)*	5	0.17	0.27	0.65	0.00
Kjeldahl Nitrogen (mg/1 N)	5	0.43	0.17	0.67	0.21
NO_2 + NO_3 (mg/1 N)*	5	0.17	0.28	0.66	0.00
Orthophosphate (mg/1 PO_4)*	5	0.02	0.04	0.09	0.00
Phosphorus (mg/1)	5	0.07	0.08	0.22	0.03
Orthophosphorus (mg/1 P)*	5	0.01	0.01	0.03	0.00
Total Organic Carbon (mg/1)	1	3.6	-------	3.6	-------
Total Inorganic Carbon (mg/1)	0	-------	-------	-------	-------
Cyanide (mg/1)	3	0.00	0.00	0.00	0.00
Sulfide (mg/1)*	5	0.2	0.2	0.5	0.0
Hardness (mg/1 Ca, Mg)	5	304.	105.	490.	240.
Non Carbonate Hardness (mg/1)	5	111.	106.	290.	80.
Calcium (mg/1)*	5	69.	13.	91.	66.
Magnesium (mg/1)*	5	32.	17.	63.	22.
Sodium (mg/1)*	5	92.	78.	230.	50.
Sodium Adsorption Ratio	5	2.2	1.3	4.5	1.4
% Sodium	5	36.	8.	50.	30.
Potassium (mg/1)*	5	2.4	1.0	4.1	1.6
Chloride (mg/1)*	5	31.	4.	37.	25.
Sulfate (mg/1)*	5	160.	20.	190.	140.
Fluoride (mg/1)*	5	0.3	0.1	0.4	0.2
Silica (mg/1)*	5	11.6	2.3	15.0	8.8
Arsenic (mg/1)*	3	0.002	0.001	0.002	0.001
Barium (mg/1)*	3	0.147	0.050	0.200	0.100
Beryllium (mg/1)*	2	<0.0005	-------	<0.0010	0.0000
Bismuth (mg/1)*	2	<0.004	-------	<0.006	<0.003
Boron (mg/1)*	3	0.062	0.018	0.080	0.045
Cadium (mg/1)*	3	0.000	0.000	0.000	0.000
Chromium (mg/1)*	3	0.006	0.005	0.010	0.000
Cobalt (mg/1)*	3	<0.001		<0.002	0.000
Copper (mg/1)*	3	0.003	0.002	0.005	0.001
Iron (mg/1)*	2	0.000	0.000	0.000	0.000
Lead (mg/1)*	3	0.001	0.002	0.004	0.000
Manganese (mg/1)*	2	0.005	0.007	0.010	0.000
Mercury (mg/1)*	3	0.0001	0.0001	0.0002	0.0000
Molybdenum (mg/1)*	3	0.004	0.002	0.006	0.002
Nickel (mg/1)*	3	0.005	0.006	0.012	0.001
Silver (mg/1)*	2	0.000	0.000	0.000	0.000
Strontium (mg/1)*	2	0.750	0.099	0.820	0.680
Vanadium (mg/1)*	3	0.0045	0.0047	0.0100	0.0015
Zinc (mg/1)*	3	0.013	0.015	0.030	0.000
Tin (mg/1)*	2	<0.005	-------	<0.006	<0.004
Aluminum (mg/1)*	2	0.025	0.021	0.040	0.010
Gallium (mg/1)*	2	<0.002	0.000	<0.002	<0.002
Germanium (mg/1)*	2	<0.005	-------	<0.006	<0.004
Lithium (mg/1)*	3	0.013	0.006	0.020	0.010
Selenium (mg/1)*	3	0.001	0.001	0.001	0.000
Titanium (mg/1)*	1	<0.002	-------	<0.002	-------
Zirconium (mg/1)*	1	<0.005	-------	<0.005	-------
Gross Beta (pc/1, Cs-137)*	1	4.7	-------	4.7	-------
Chlorophyll A (mg/1)	3	0.0013	0.0003	0.0015	0.0009
Chlorophyll B (mg/1)	3	0.0012	0.0004	0.0015	0.0008
Phenols (mg/1)	5	0.003	0.002	0.005	0.001
Dissolved Solids (mg/1)*	4	468.	33.	517.	452.
Gross Alpha (mg/1 U)*	1	0.014	-------	0.014	-------
Gross Beta (pc/1, SR_{90}/Y_{90})*	1	3.5	-------	3.5	-------
Bromide (mg/1)	5	0.1	0.04	0.1	0.0

* Elements analyzed for dissolved fraction

APPENDIX II-19

SUMMARY OF SURFACE WATER QUALITY
EVACUATION CREEK AT MOUTH (S-2) BASE FLOW
July 14, 1975-January 8, 1976

Description	Number of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (oC)	10	16.3	9.3	30.0	0.5
Turbidity (JTU)	8	4132.	11664.	33000.	0.
Conductance (µmhos)	10	3952.	1197.	5100.	1200.
Chemical Oxygen Demand (mg/l)	8	348.	910.	2600.	20.
pH (pH units)	9	7.8	0.6	9.0	7.3
Carbon Dioxide (mg/l)	8	18.	10.	30.	0.7
Alkalinity (mg/l $CACO_3$)	9	35.3	100.	435.	125.
Bicarbonate (mg/l HCO_3)	9	431.	122.	530.	152.
Carbonate (mg/l CO_3)	8	0.	0.	0.	0.
Filterable Residue (mg/l)	3	3467.	586.	3900.	2800.
Oil & Grease (mg/l)	7	0.3	0.5	1.	0.
Ammonia (mg/l N)*	8	0.02	0.02	0.04	0.00
Nitrite (mg/l N)*	8	0.02	0.01	0.03	0.01
Nitrate (mg/l N)*	8	0.37	0.43	1.1	0.01
Kjeldahl Nitrogen (mg/l N)	8	0.77	0.72	2.5	0.16
NO_2 + NO_3 (mg/l N)*	8	0.39	0.45	1.1	0.02
Orthophosphate (mg/l PO_4)*	9	0.017	0.022	0.06	0.00
Phosphorus (mg/l)	8	0.008	0.014	0.04	0.00
Orthophosphorus (mg/l P)*	9	0.005	0.007	0.02	0.00
Total Organic Carbon (mg/l)	2	13.5	---------	15.	12.
Total Inorganic Carbon (mg/l)	1	--------	---------	114.	--------
Cyanide (mg/l)	5	0.00	0.00	0.00	0.00
Sulfide (mg/l)*	8	0.10	0.09	0.2	0.0
Hardness (mg/l Ca, Mg)	9	991.	303.	1200.	260.
Non Carbonate Hardness (mg/l)	9	618.	196.	770.	130.
Calcium (mg/l)*	9	164.	41.	200.	62.
Magnesium (mg/l)*	9	137.	52.	170.	25.
Sodium (mg/l)*	9	608.	219.	760.	160.
Sodium Adsorption Ratio	9	8.3	2.1	10.	4.3
% Sodium	9	57.	4.0	60.	47.
Potassium (mg/l)*	9	8.6	1.3	11.	7.4
Chloride (mg/l)*	9	44.	13.	57.	20.
Sulfate (mg/l)*	9	1859.	632.	2300.	430.
Fluoride (mg/l)*	9	0.76	0.11	0.9	0.6
Silica (mg/l)*	9	9.2	1.5	11.	6.9
Arsenic (mg/l)*	5	0.0012	0.0008	0.002	0.000
Barium (mg/l)*	5	<0.140	0.055	0.200	<0.100
Beryllium (mg/l)*	2	0.010	-------	0.010	0.010
Bismuth (mg/l)*	0	-------	-------	--------	--------
Boron (mg/l)*	6	1.508	0.625	1.900	0.250
Cadium (mg/l)*	5	0.0002	0.0004	0.001	0.000
Chromium (mg/l)*	5	<0.006	0.005	0.010	0.000
Cobalt (mg/l)*	5	0.0006	0.0005	0.001	0.000
Copper (mg/l)*	6	0.009	0.010	0.029	0.002
Iron (mg/l)*	6	0.042	0.078	0.200	0.000
Lead (mg/l)*	5	0.0004	0.0005	0.001	0.000
Manganese (mg/l)*	6	0.077	0.040	0.130	0.030
Mercury (mg/l)*	5	0.0000	0.0000	0.0000	0.0000
Molybdenum (mg/l)*	5	0.046	0.006	0.053	0.039
Nickel (mg/l)*	5	0.004	0.002	0.006	0.001
Silver (mg/l)*	2	0.000	-------	0.000	0.000
Strontium (mg/l)*	2	4.000	-------	4.100	3.900
Vanadium (mg/l)*	5	0.0009	0.0003	0.0013	0.0006
Zinc (mg/l)*	5	0.010	0.000	0.010	0.010
Tin (mg/l)*	0	-------	-------	-------	-------
Aluminum (mg/l)*	5	0.012	0.008	0.020	0.000
Gallium (mg/l)*	0	-------	-------	-------	-------
Germanium (mg/l)*	0	-------	-------	-------	-------
Lithium (mg/l)*	5	0.124	0.027	0.170	0.100
Selenium (mg/l)*	5	0.0014	0.0017	0.004	0.000
Titanium (mg/l)*	0	-------	-------	-------	-------
Zirconium (mg/l)*	0	-------	-------	-------	-------
Gross Beta (pc/l, Cs-137)*	3	<23.	14.	37.	<9.5
Chlorophyll A (mg/l)	5	0.0014	0.0014	0.0032	0.0000
Chlorophyll B (mg/l)	5	0.005	0.007	0.0017	0.0000
Phenols (mg/l)	8	0.0034	0.0037	0.012	0.000
Dissolved Solids (mg/l)*	8	3455.	634.	3970.	2150.
Gross Alpha (mg/l U)*	3	<0.049	0.023	0.062	<0.023
Gross Beta (pc/l SR_{90}/Y_{90})*	3	<19.8	13.3	34.	<7.5
Bromide (mg/l)	3	0.	0.06	0.3	0.2

* Elements analyzed for dissolved fraction

APPENDIX II-20

SUMMARY OF SURFACE WATER QUALITY
WHITE RIVER NEAR WATSON (S-3)
BASE FLOW - AUG. 4, 1975 - JAN. 5, 1976

Description	Number of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	9	11.1	8.1	21.0	0.0
Turbidity (JTU)	8	28.	26.	76.	1.
Conductance (µmhos)	9	743.	112.	996.	625.
Chemical Oxygen Demand (mg/l)	8	10.	7.	21.	1.
pH (pH units)	8	8.3	0.3	8.8	8.0
Carbon Dioxide (mg/l)	8	2.1	1.3	4.0	0.6
Alkalinity (mg/l $CaCO_3$)	9	188.	11.	205.	174.
Bicarbonate (mg/l HCO_3)	9	228.	13.	250.	212.
Carbonate (mg/l CO_3)	9	1.	2.	6.	0.
Filterable Residue (mg/l)	3	513.	32.	550.	490.
Oil & Grease (mg/l)	8	0.3	0.5	1.	0.
Ammonia (mg/l N)*	8	0.01	0.01	0.04	0.00
Nitrite (mg/l N)*	8	0.001	0.004	0.01	0.00
Nitrate (mg/l N)*	8	0.10	0.14	0.35	0.00
Kjeldahl Nitrogen (mg/l N)	8	0.50	0.22	0.86	0.25
$NO_2 + NO_3$ (mg/l N)*	9	0.09	0.13	0.35	0.00
Orthophosphate (mg/l PO_4)*	9	0.02	0.02	0.06	0.00
Phosphorus (mg/l)	8	0.07	0.08	0.23	0.00
Orthophosphorus (mg/l P)*	9	0.01	0.01	0.02	0.00
Total Organic Carbon (mg/l)	2	3.2	0.1	3.3	3.1
Total Inorganic Carbon (mg/l)	1	53.	-------	53.	-------
Cyanide (mg/l)	6	0.00	0.00	0.00	0.00
Sulfide (mg/l)*	8	0.3	0.7	1.9	0.0
Hardness (mg/l Ca, Mg)	9	273.	15.	300.	250.
Non Carbonate Hardness (mg/l)	9	84.	70.	96.	74.
Calcium (mg/l)*	9	67.	5.	79.	60.
Magnesium (mg/l)*	9	25.	2.	29.	23.
Sodium (mg/l)*	9	60.	6.	70.	52.
Sodium Adsorption Ratio	9	1.6	0.2	1.9	1.4
% Sodium	9	32.	2.	36.	30.
Potassium (mg/l)*	9	2.0	0.3	2.5	1.7
Chloride (mg/l)*	9	32.	4.	39.	25.
Sulfate (mg/l)*	9	163.	12.	180.	150.
Fluoride (mg/l)*	9	0.3	0.0	0.3	0.2
Silica (mg/l)*	9	12.5	2.2	15.0	8.9
Arsenic (mg/l)*	6	0.001	0.001	0.001	0.000
Barium (mg/l)*	6	<0.116	-------	0.200	0.000
Beryllium (mg/l)*	2	0.000	0.000	0.000	0.000
Bismuth (mg/l)*	1	<0.003	-------	<0.003	-------
Boron (mg/l)*	7	0.066	0.015	0.090	0.050
Cadmium (mg/l)*	6	0.000	0.0004	0.001	0.000
Chromium (mg/l)*	6	<0.006	-------	0.010	0.000
Cobalt (mg/l)*	6	0.001	0.001	0.001	0.000
Copper (mg/l)*	6	0.004	0.003	0.009	0.001
Iron (mg/l)*	6	0.033	0.059	0.150	0.000
Lead (mg/l)*	6	0.0002	0.0004	0.001	0.000
Manganese (mg/l)*	6	0.004	0.005	0.010	0.000
Mercury (mg/l)*	6	0.00003	0.00005	0.0001	0.0000
Molybdenum (mg/l)*	6	0.003	0.001	0.004	0.002
Nickel (mg/l)*	6	0.003	0.002	0.005	0.000
Silver (mg/l)*	2	0.000	0.000	0.000	0.000
Strontium (mg/l)*	2	0.925	0.077	0.980	0.870
Vanadium (mg/l)*	6	0.0021	0.0005	0.0027	0.0014
Zinc (mg/l)*	6	0.007	0.008	0.020	0.000
Tin (mg/l)*	1	<0.003	-------	<0.003	-------
Alumina (mg/l)*	6	0.022	0.013	0.040	0.000
Gallium (mg/l)*	1	<0.002	-------	<0.002	-------
Germanium (mg/l)*	1	<0.007	-------	<0.007	-------
Lithium (mg/l)*	6	0.012	0.004	0.020	0.010
Selenium (mg/l)*	6	0.001	0.000	0.001	0.001
Titanium (mg/l)*	1	<0.002	-------	<0.002	-------
Zirconium (mg/l)*	1	<0.005	-------	<0.005	-------
Gross Beta (Pc/l, Cs-137)*	3	2.8	1.1	4.1	1.9
Chlorophyll A (mg/l)	6	0.0012	0.0006	0.0018	0.0004
Chlorophyll B (mg/l)	6	0.0009	0.0012	0.0031	0.0000
Phenols (mg/l)	8	0.005	0.003	0.011	0.002
Dissolved Solids (mg/l)*	8	489.	28.	533.	456.
Gross Alpha (mg/l U)*	3	<0.0084	-------	0.0094	<0.0069
Gross Beta (Pc/l, Sr_{90}/Y_{90})*	3	2.3	0.8	3.2	1.6
Bromide (mg/l)	8	0.1	0.04	0.1	0.0

* Elements analyzed for dissolved fraction

APPENDIX II-21

SUMMARY OF SURFACE WATER QUALITY
EVACUATION CREEK AT WATSON (S-6)
BASE FLOW - JULY 25, 1975 - JAN. 6, 1976

Description	Number of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	9	12.6	7.9	22.3	2.0
Turbidity (JTU)	8	1756.	4555.	13000.	2.
Conductance (umhos)	9	4140.	1994.	5200.	454.
Chemical Oxygen Demand (mg/l)	8	140.	265.	790.	34.
pH (pH units)	7	7.7	0.3	8.1	7.4
Carbon Dioxide (mg/l)	6	12.5	8.7	28.	1.9
Alkalinity (mg/l $CACO_3$)	8	373.	153.	487.	126.
Bicarbonate (mg/l HCO_3)	8	454.	187.	594.	153.
Carbonate (mg/l CO_3)	8	0.	0.	0.	0.
Filterable Residue (mg/l)	2	2420.	-------	4100.	740.
Oil & Grease (mg/l)	7	2.0	4.4	12.	0.
Ammonia (mg/l N)*	8	0.009	0.016	0.04	0.00
Nitrite (mg/l N)*	8	0.016	0.017	0.05	0.00
Nitrate (mg/l N)*	8	0.72	1.71	4.9	0.00
Kjeldahl Nitrogen (mg/l N)	8	1.78	1.39	4.7	0.67
NO_2 + NO_3 (mg/l N)*	8	0.75	1.70	4.9	0.00
Orthophosphate (mg/l PO_4)*	8	0.018	0.022	0.06	0.00
Phosphorus (mg/l)	8	1.05	2.44	7.0	0.00
Orthophosphorus (mg/l P)*	8	0.006	0.007	0.02	0.00
Total Organic Carbon (mg/l)	2	16.5	-------	17.	16.
Total Inorganic Carbon (mg/l)	1	123.	-------	123.	-------
Cyanide (mg/l)	5	0.00	0.00	0.00	0.00
Sulfide (mg/l)*	8	0.13	0.10	0.3	0.0
Hardness (mg/l CO, Mg)	8	1023.	523.	1400.	180.
Non Carbonate Hardness (mg/l)	8	654.	374.	960.	48.
Calcium (mg/l)*	8	160.	70.	210.	49.
Magnesium (mg/l)*	8	152.	84.	220.	14.
Sodium (mg/l)*	8	741.	412.	980.	29.
Sodium Adsorption Ratio	8	9.3	4.4	12.	3.6
% Sodium	8	56.1	12.5	63.	26.
Potassium (mg/l)*	8	8.5	3.2	12.	1.9
Chloride (mg/l)*	8	49.	23.	75.	12.
Sulfate (mg/l)*	8	2125.	1202.	3000.	83.
Fluoride (mg/l)*	8	0.81	0.29	1.1	0.2
Silica (mg/l)*	8	10.4	2.6	14.	5.5
Arsenic (mg/l)*	5	0.0022	0.0015	0.004	0.000
Barium (mg/l)*	5	<0.140	0.114	<0.300	0.000
Beryllium (mg/l)*	3	<0.009	0.002	0.010	<0.006
Bismuth (mg/l)*	1	0.040		<0.040	
Boron (mg/l)*	5	1.826	0.926	2.600	0.230
Cadmium (mg/l)*	5	0.000	0.000	0.000	0.000
Chromium (mg/l)*	5	<0.006	0.005	0.010	0.000
Cobalt (mg/l)*	5	0.0004	0.0005	0.001	0.000
Copper (mg/l)*	5	0.013	0.012	0.031	0.003
Iron (mg/l)*	5	0.036	0.043	0.110	0.000
Lead (mg/l)*	5	0.0006	0.0013	0.003	0.000
Manganese (mg/l)*	5	0.184	0.150	0.410	0.010
Mercury (mg/l)*	5	0.00002	0.00004	0.0001	0.0000
Molybdenum (mg/l)*	5	0.031	0.015	0.043	0.007
Nickel (mg/l)*	5	0.006	0.002	0.008	0.003
Silver (mg/l)*	3	<0.001	0.002	<0.003	0.000
Strontium (mg/l)*	3	4.133	0.115	4.200	4.000
Vanadium (mg/l)*	5	0.0009	0.0004	0.0013	0.0004
Zinc (mg/l)*	5	0.014	0.015	0.040	0.000
Tin (mg/l)*	1	0.040	-------	<0.040	-------
Aluminum (mg/l)*	5	0.030	0.035	0.090	0.010
Gallium (mg/l)*	1	-------	-------	<0.010	-------
Germanium (mg/l)*	1	-------	-------	<0.025	-------
Lithium (mg/l)*	5	0.092	0.050	0.140	0.010
Selenium (mg/l)*	5	0.0004	0.0005	0.001	0.000
Titanium (mg/l)*	1	0.030	-------	0.030	-------
Zirconium (mg/l)*	1	0.050	-------	<0.050	-------
Gross Beta (PC/L, CS-137)*	2	22.	-------	26.	18.
Chlorophyll A (mg/l)	5	0.0033	0.0028	0.0068	0.0004
Chlorophyll B (mg/l)	5	0.0026	0.0025	0.0066	0.0002
Phenols (mg/l)	8	0.0045	0.0026	0.009	0.001
Dissolved Solids (mg/l)*	8	36480.	1985.	4920.	281.
Gross Alpha (mg/l U)*	2	<0.026	-------	<0.043	<0.010
Gross Beta (PC/L Sr_{90}/Y_{90})*	2	18.	-------	21.	15.
Bromide (mg/l)	1	0.4	-------	0.4	-------

*Elements analyzed for dissolved fraction

APPENDIX II-22

SUMMARY OF WATER QUALITY
WHITE RIVER ABV. SOUTHAM CAN. NEAR WATSON (S-4)
BASE FLOW - AUG. 6, 1975 - DEC. 1, 1975

Description	Number of Samples	Mean	Standard Deviation	Maximum	Minimum
Temperature (°C)	6	12.9	8.5	22.0	0.5
Turbidity (JTU)	6	27.	20.	60.	2.
Conductance (μmhos)	6	737.	29.	780.	700.
Chemical Oxygen Demand (mg/l)	6	10.	5.	17.	2.
pH (pH Units)	4	8.3	0.4	8.7	7.7
Carbon Dioxide (mg/l)	4	5.1	3.2	7.8	0.7
Alkalinity (mg/l $CACO_3$)	6	189.	10.	199.	178.
Bicarbonate (mg/l HCO_3)	6	229.	13.	243.	210.
Carbonate (mg/l CO_3)	5	0.6	0.9	2.0	0.0
Filterable Residue (mg/l)	2	590.	141.	690.	490.
Oil & Grease (mg/l)	6	0.2	0.4	1.	0.
Ammonia (mg/l N)*	6	0.01	0.02	0.04	0.00
Nitrite (mg/l N)*	6	0.003	0.005	0.01	0.00
Nitrate (mg/l N)*	6	0.04	0.08	0.20	0.00
Kjeldahl Nitrogen (mg/l N)	6	0.48	0.31	1.10	0.25
NO_2 + NO_3 (mg/l N)*	6	0.05	0.08	0.21	0.00
Orthoposphate (mg/l PO_4)*	6	0.02	0.03	0.06	0.00
Phosphorus (mg/l)	6	0.11	0.18	0.47	0.02
Orthoposphorus (mg/l P)*	6	0.01	0.01	0.02	0.00
Total Organic Carbon (mg/l)	1	7.3		7.3	
Total Inorganic Carbon (mg/l)	0	-------	-------	-------	-------
Cyanide (mg/l)	4	0.00	0.00	0.00	0.00
Sulfide (mg/l)*	6	0.4	0.8	2.0	0.0
Hardness (mg/l Ca, Mg)	6	270.	11.	280.	260.
Non Carbonate Hardness (mg/l)	6	80.	6.	84.	68.
Calcium (mg/l)*	6	66.	4.	73.	62.
Magnesium (mg/l)*	6	26.	3.	30.	23.
Sodium (mg/l)*	6	60.	8.	74.	52.
Sodium Adsorption Ratio	6	1.6	0.2	1.9	1.4
% Sodium	6	32.	3.	37.	30.
Potassium (mg/l)*	6	2.0	0.4	2.4	1.6
Chloride (mg/l)*	6	32.	4.	37.	26.
Sulfate (mg/l)*	6	162.	19.	190.	140.
Fluoride (mg/l)*	6	0.3	0.0	0.3	0.2
Silica (mg/l)*	6	12.1	2.4	15.0	8.4
Arsenic (mg/l)*	4	0.0005	0.0006	0.0010	0.0000
Barium (mg/l)*	4	<0.125	<0.050	<0.200	<0.100
Beryllium (mg/l)*	1	0.000		0.000	
Bismuth (mg/l)*	1	<0.003		<0.003	
Boron (mg/l)*	4	0.088	0.013	0.100	0.070
Cadmium (mg/l)*	4	0.0003	0.0005	0.001	0.000
Chromium (mg/l)*	4	<0.005	<0.006	0.010	0.000
Cobalt (mg/l)*	4	0.000	0.000	0.000	0.000
Copper (mg/l)*	4	0.003	0.001	0.003	0.002
Iron (mg/l)*	4	0.003	0.005	0.010	0.000
Lead (mg/l)*	4	0.002	0.002	0.005	0.000
Manganese (mg/l)*	4	0.003	0.005	0.010	0.000
Mercury (mg/l)*	4	0.0001	0.0001	0.0002	0.0000
Molybdenum (mg/l)*	4	0.003	0.001	0.004	0.002
Nickel (mg/l)*	4	0.004	0.002	0.006	0.002
Silver (mg/l)*	1	0.000		0.000	
Strontium (mg/l)*	1	0.820		0.820	
Vanadium (mg/l)*	4	0.0019	0.0003	0.0022	0.0015
Zinc (mg/l)*	4	0.008	0.005	0.010	0.000
Tin (mg/l)*	1	<0.003	0.000	<0.003	<0.003
Aluminum (mg/l)*	4	0.020	0.008	0.030	0.010
Gallium (mg/l)*	1	<0.002		<0.002	
Germanium (mg/l)*	1	<0.007		<0.007	
Lithium (mg/l)*	4	0.008	<0.005	0.010	0.000
Selenium (mg/l)*	4	0.001	0.000	0.001	0.001
Titanium (mg/l)*	1	<0.002		<0.002	
Zirconium (mg/l)*	1	<0.005		<0.005	
Gross Beta (pc/l, Cs-137)*	2	8.3	6.7	13.0	3.6
Chlorophyll A (mg/l)	2	0.0050	0.0054	0.0088	0.0012
Chlorophyll B (mg/l)	2	0.0080	0.0099	0.0150	0.0009
Phenols (mg/l)	6	0.002	0.002	0.005	0.001
Dissolved Solids (mg/l)*	6	485.	25.	522.	459.
Gross Alpha (mg/l U)*	2	0.0117	0.0075	0.0170	0.0064
Gross Beta (pc/l, SR_{90}/Y_{90})*	2	6.4	5.1	10.0	2.8
Bromide (mg/l)	6	0.11	0.04	0.1	0.0

* Elements analyzed for dissolved fraction

APPENDIX II-23

MONTHLY COLIFORM DATA

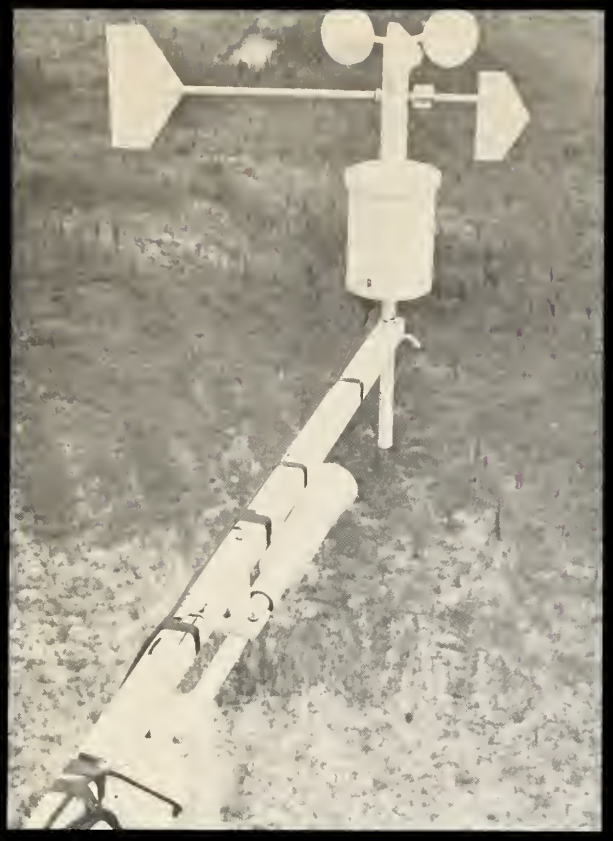
Date	Station	Total	Fecal	Fecal Strep	FC/FS Ratio
Jan 24 1975	S-1	64	50	34	1.5
	S-3	64	50	17	2.9
	S-4	26	34	17	2.0
	S-11	40	23	23	1.0
Feb 13-14	S-1	114	20	17	1.2
	S-2	0	0	1	---
	S-3	175	16	32	0.5
	S-4	104	22	20	0.1
	S-6	0	0	25	0.05±
	S-11	134	21	37	0.6
March 12-13	S-1	320	65	144	0.4
	S-2	0	0	16	0.06
	S-3	180	26	163	0.2
	S-4	250	30	180	0.2
	S-6	0	0	20	0.05±
	S-7	0	14	112	0.1
	S-11	240	49	142	0.3
April 15-16	S-1	24	4	11	0.4
	S-2	48	31	37	0.8
	S-3	12	7	8	0.9
	S-4	40	4	10	0.4
	S-6	0	6	21	0.3
	S-7	20	48	82	0.6
	S-11	80	2	4	0.5
May 13-14	S-1	280.	120.	22.*	5.4*
	S-2	12.	9.	19.	0.5
	S-3	380.	220.	203.	1.1
	S-4	530.	230.	233.	1.0
	S-6	0	0	32	---
	S-7	9	6	24	0.2
	S-11	440.	250	253	1.0

*Questionable values due to heavy silt in sample

APPENDIX II-23 Con't.

Date	Station	Total	Fecal	Fecal Strep	FC/FS Ratio
June 23-24	S-1	170.	12.	172.	0.1
	S-2	1070.	4.	305.	0.01
	S-3	140.	16.	120.	0.1
	S-4	100.	66.	110.	0.6
	S-6	1250.	1	173.	0.01
	S-7	600.	10.	326.	0.03
	S-11	120.	24.	144.	0.2
July 13-14	S-1	230.	80.	360.	0.2
	S-2	1400.	6620.	3680.	1.8
	S-3	230.	96.	270.	0.4
	S-4	320.	124.	300.	0.4
	S-6	1720.	1860.	1580.	1.2
	S-7	1360.	1900.	2880.	0.7
	S-11	380.	316.	680.	0.5
Aug 11-12	S-1	58.	81.	25.*	3.2*
	S-2	1185.	1440.	2580.	0.6
	S-3	60.	102.	163.	0.6
	S-4	0	68.	77.	0.9
	S-6	950.	1620.	2630.	0.6
	S-7	865.	670.	1370.	0.5
	S-11	0	35.	59.	0.6
Sept 8-9	S-1	0	0	4.	---
	S-2	0	2.	149.	.01
	S-3	0	0	10.	---
	S-4	0	3.	17.	0.2
	S-6	0	2.	44.	.05
	S-11	0	6.	22.	0.3

*Questionable values due to heavy silt in sample



III
AIR
RESOURCES

III. AIR RESOURCES

The Oil Shale Lease Stipulations specify the scope of the meteorological and air quality baseline data collection activities in Section 1, Paragraph (C) (2) (c), as amended October 1974 for meteorology and November 1974 for air quality.

The equipment and parameters measured were in compliance with the lease agreement during the first year baseline period (January 16, 1975 through January 15, 1976).

Field observations, along with a comprehensive data validation program was instituted which indicated that, within the mechanical limitations of the monitoring equipment used, the data accurately described the baseline conditions at the tracts. (Compliance tables can be found in the 6th Quarterly Baseline Field Data Reports.)

A. METEOROLOGY

Little is known about the regional meteorology of the Uinta Basin. The terrain of the Tracts U-a and U-b area is complex and rugged, which significantly influences meteorological factors related to air pollution dispersion. Elevations vary from 1,460 m (4,800 ft) above sea level at the White River to 1,800 m (5,900 ft) above sea level just south of the tracts, with many gentle hills and a few sharp ravines. Elevations are much higher about 25 km (40 mi) to the south of the tracts and to the west and the east.

The dry air is expected to cause low-level nocturnal inversions that will tend to inhibit effluent dispersion, especially during winter and summer. Extreme temperature variations and clear nights are expected to cause topographically-controlled surface drainage flows. Surface roughness will probably produce moderate to strong turbulence and therefore moderate to strong effluent dispersion, except during very light winds.

The mesoscale/microscale mean air flows and turbulence are not fully understood for this kind of terrain, and climatological data do not exist for the specific area. Historical data form the nearest radiosonde station in Grand Junction, Colorado (about 40 km (65 mi) SSE), are summarized in Table III-1 for the mean seasonal and annual morning and afternoon mixing heights and wind speeds through these layers.

TABLE III-1

MEAN MIXING HEIGHTS AND WIND SPEEDS
GRAND JUNCTION, COLORADO

	Mixing Height in meters (feet)		Wind Speed in m/s (mph)	
Season	Morning	Afternoon	Morning	Afternoon
Winter	329 (1,079)	1,161 (3,806)	3.4 (7.6)	3.4 (7.6)
Spring	628 (2,060)	3,168 (10,387)	5.4 (12.1)	6.6 (14.8)
Summer	307 (1,007)	3,942 (12,926)	4.7 (10.5)	6.1 (13.6)
Autumn	273 (896)	2,134 (6,998)	3.9 (8.7)	4.6 (10.3)
Annual	384 (1,260)	2,602 (8,530)	4.3 (9.6)	5.2 (11.6)

SOURCE: Holzworth, 1972.

Regional weather stations measuring temperature and/or precipitation in the vicinity of the tracts include the following sites: Bonanza, Jensen, Dinosaur, Vernal, and Fort Duchense in Utah; Rangely in Colorado.

1. SURFACE METEOROLOGY

a. Objectives

The objectives of the meteorology program are unusual for this kind of study, which is usually concerned only with establishing a baseline with which to monitor future changes. The data from this program will be used for planning and designing developments in and around the tract area and for analyzing diffusivity of the atmosphere (see Section III.B).

b. Methodology

Meteorology was measured continuously during the first year at all 12 air resources monitoring sites in and around the tracts, as shown in Figure III-1. At all of these stations, cup and vane anemometers recorded wind speed and direction at 10 m (30 ft) above the ground. In addition, temperature at the same height was measured at seven stations. Three of these stations (Stations A-2, A-4, and A-6) had thermistor sensors in aspirated vacuum-bottle radiation shields and four (Stations A-9 through A-12) had north-facing shaded bimetallic thermometers.

Two of the monitoring stations--Station A-2 on Tract U-a and Station A-6 on Tract U-b--had meteorological equipment on 30-m (100-ft) masts that monitored several parameters in addition to those recorded at the 10-m (33-ft) level at the other sites. To establish the lapse rate between 10 m and 30 m, both stations recorded wind speed and wind direction at 20 m and 30 m and measured temperature at 30 m using sensors identical to those used at 10 m. In addition, both stations measured the dew point at 10 m using a cooled mirror hygrometer. To supplement the hygrometer, a hair hygrograph was added to the equipment complement at Station A-6 in late 1975 to measure relative humidity; a Fritschen net radiometer was used at the station to measure the net radiation flux, and an aneroid barograph with capacitance sensing was used to measure the barometric pressure. These continuous records were supplemented by a regular program of instantaneous observations and measurements, including a twice-daily record of the general meteorological situation (clouds, wind, precipitation, ground cover, etc.) and frequent measurements of wet-bulb/dry-bulb temperatures and barometric pressure with a mercury barometer.

Additional surface meteorological measurements were concerned with atmospheric turbulence. Lateral turbulence, electronically computed from the root-mean-square fluctuations of a wind vane and denoted σ_θ, was measured throughout the year at the 30-m levels of the towers at Stations A-2 and A-6 and at the 10-m level at Station A-4. Vertical turbulence (σ_w), obtained from the root-mean-square speed of a vertically oriented propeller anemometer, was also measured at these locations after April 1975. Precipitation measurements were considered part of the water resources program and are discussed in Section II.

Each measurement device was calibrated at the start of the study, and since then appropriate checks on performance

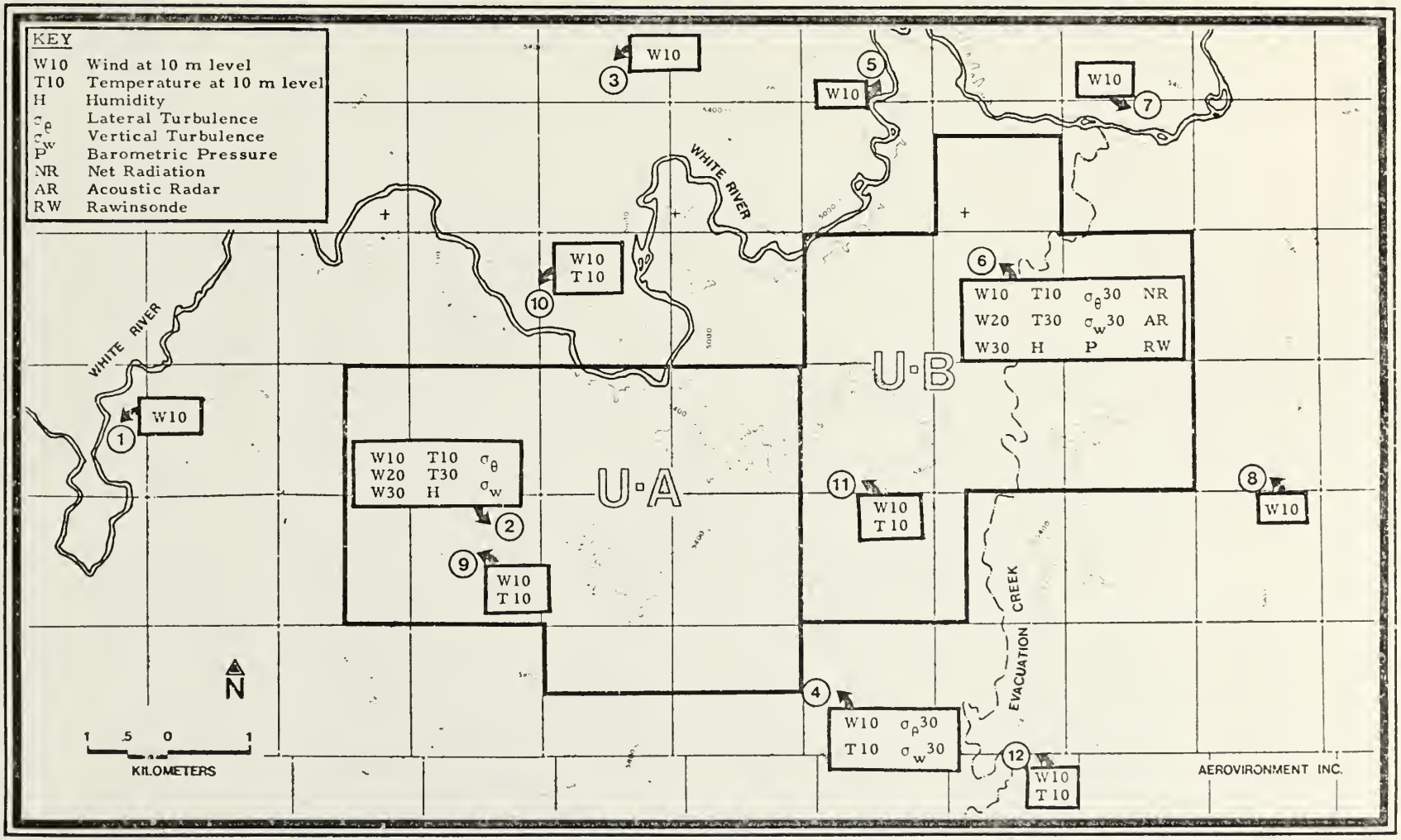


FIGURE III-1. LOCATIONS OF METEOROLOGICAL MEASUREMENT STATIONS ON TRACTS U-a AND U-b.

and calibration have been made at least quarterly or more frequently as required. Reasonable estimates of the accuracy of the data obtained from the most common sensors are tabulated in Table III-2. These numbers help establish the confidence to be placed in the data. In this regard, it should be noted that site-specific factors, such as the exact sensor location relative to topographic features and the sensor height, contribute considerably more to the variability of the data than do the accuracy limits in Table III-2.

c. Summary of Results

The surface airflow pattern on the tracts is complicated by the effects of the rugged terrain in the area. During the early morning hours, drainage flows were prevalent throughout the year, with airflows toward low terrain and down the White River channel. A typical early morning airflow pattern on the tracts is given in Figure III-2. In the afternoons the winds were stronger and more organized. The flow was generally from the west or southwest, with some variation from season to season. Typical afternoon airflow patterns for each of the seasons are given in Figures III-3 through III-6. The solid arrows are wind vectors at monitoring sites, and the longer lines are estimated-flow streamlines. Anomalies at Stations A-4 and A-5 can be attributed to vortical motions induced by the topography surrounding these locations.

Figure III-7 shows a typical diurnal variation of wind speed on the tracts for most of the year. The diurnal trend is shown only for July, but not much deviation from this trend was observed in the other months except during winter, when wind speeds were generally lower. The diurnal trend for a typical winter month is given in Figure III-8.

The relative percentage frequency distribution of wind speed at Station A-6 throughout the year is given in Figure III-9. Low winds (below 1.3 m/s, or 3 mph) were most prevalent in the winter, with a 15 percent frequency of occurrence, and were mostly from the west. Low winds were least common in the fall (4 percent frequency of occurrence) and were usually from the southwest. In spring and summer low winds occurred 8 percent of the time, from the southeast.

High winds (greater than 8 m/s, or 18 mph), usually from the southwest, occurred most often in the spring. During winter, high winds occurred with only a 2 percent frequency and came usually from the west. High winds were equally frequent (9 percent) in summer and fall and came usually from the southwest.

TABLE III-2

ESTIMATED RMS ACCURACY OF MAJOR METEOROLOGICAL MEASUREMENTS

Component	Calibration Accuracy (1)	System (1) Accuracy (2)	Total Accuracy (1)
Wind Speed (3)	± 0.05 m/s	± 2% or 0.25 m/s	±2% or 0.25 m/s
Wind Direction (3)	± 1°	± 3°	±3°
Temperature	± 0.05°C	± 0.15°C	±0.2°C
ΔT	± 0.07°C	± 0.10°C	±0.15°C
Dew Point	± 1°C	± 2°C	±2°C

Notes:

(1) The larger of the values given applies.

(2) Total for all portions, including installation, recorder, and readout.

(3) Figures apply above the nominal starting threshold of 0.3 m/s.

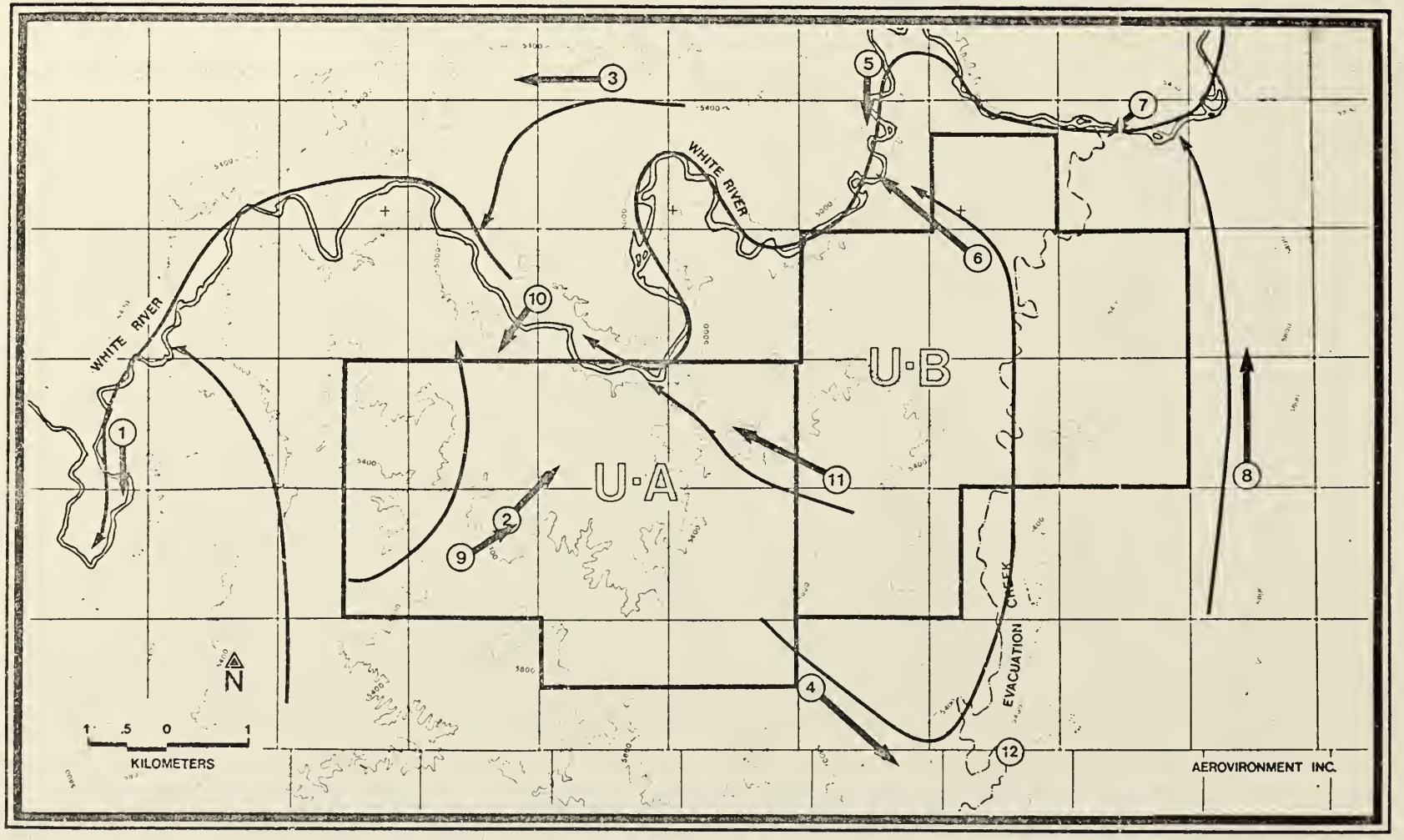


FIGURE III-2. TYPICAL EARLY MORNING AIRFLOW PATTERN ON THE TRACTS. This chart is specific for the autumn season, but is representative of all seasons.

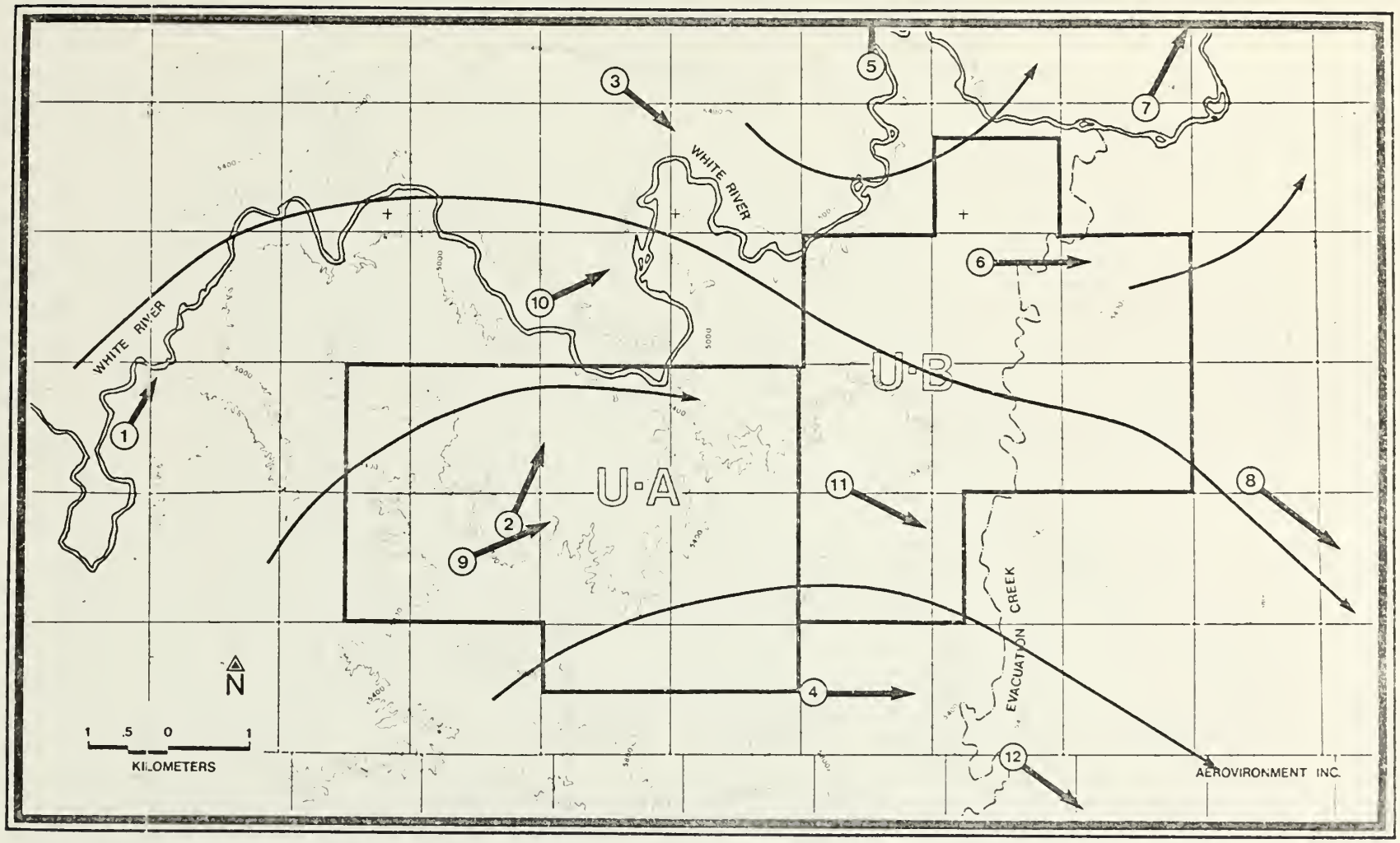


FIGURE III-3. TYPICAL AFTERNOON SURFACE AIRFLOW PATTERN ON THE TRACTS IN WINTER.

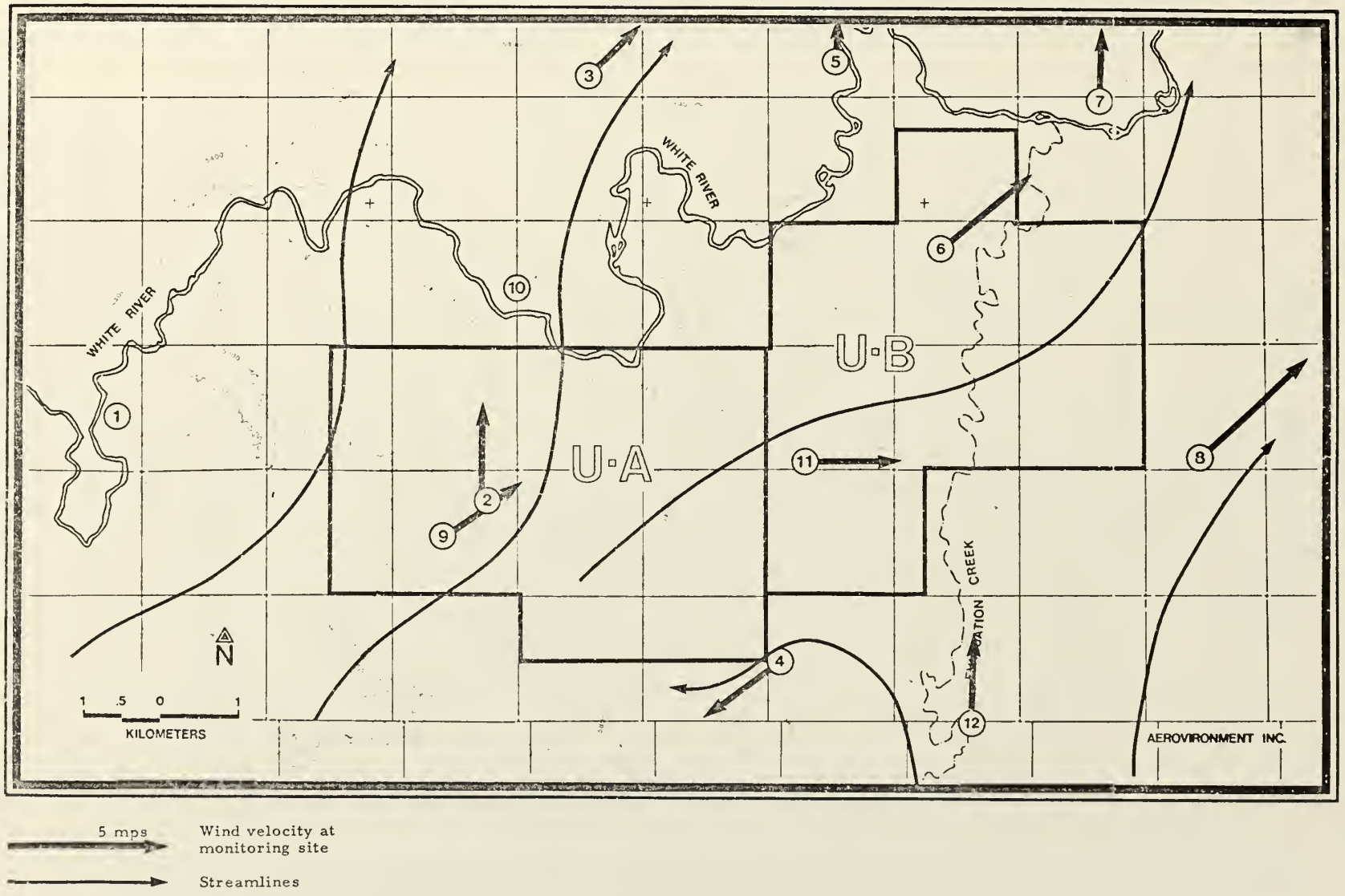


FIGURE III-4. TYPICAL AFTERNOON SURFACE AIRFLOW PATTERN ON THE TRACTS IN SPRING.

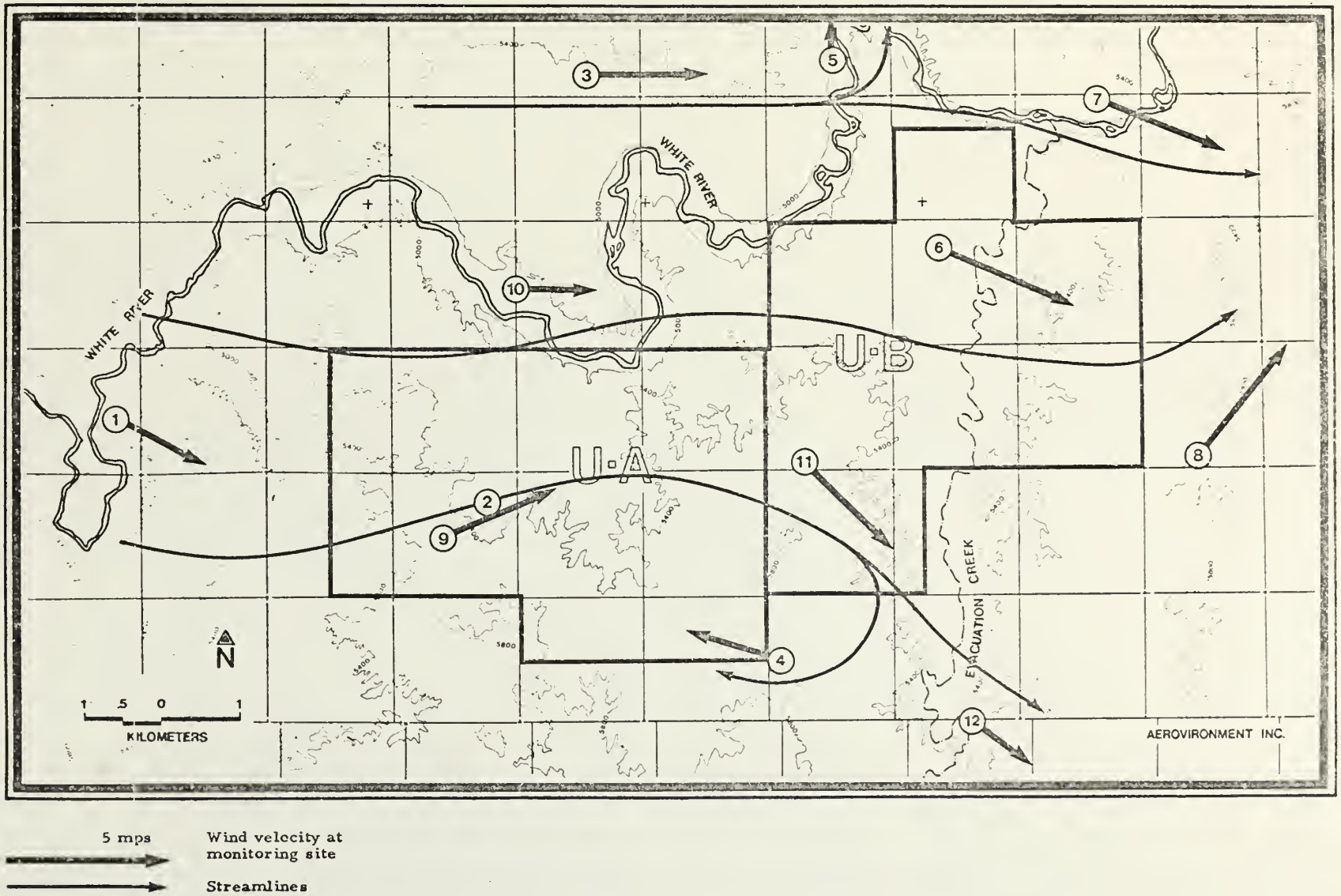


FIGURE III-5. TYPICAL AFTERNOON SURFACE AIRFLOW PATTERN ON THE TRACTS IN SUMMER.

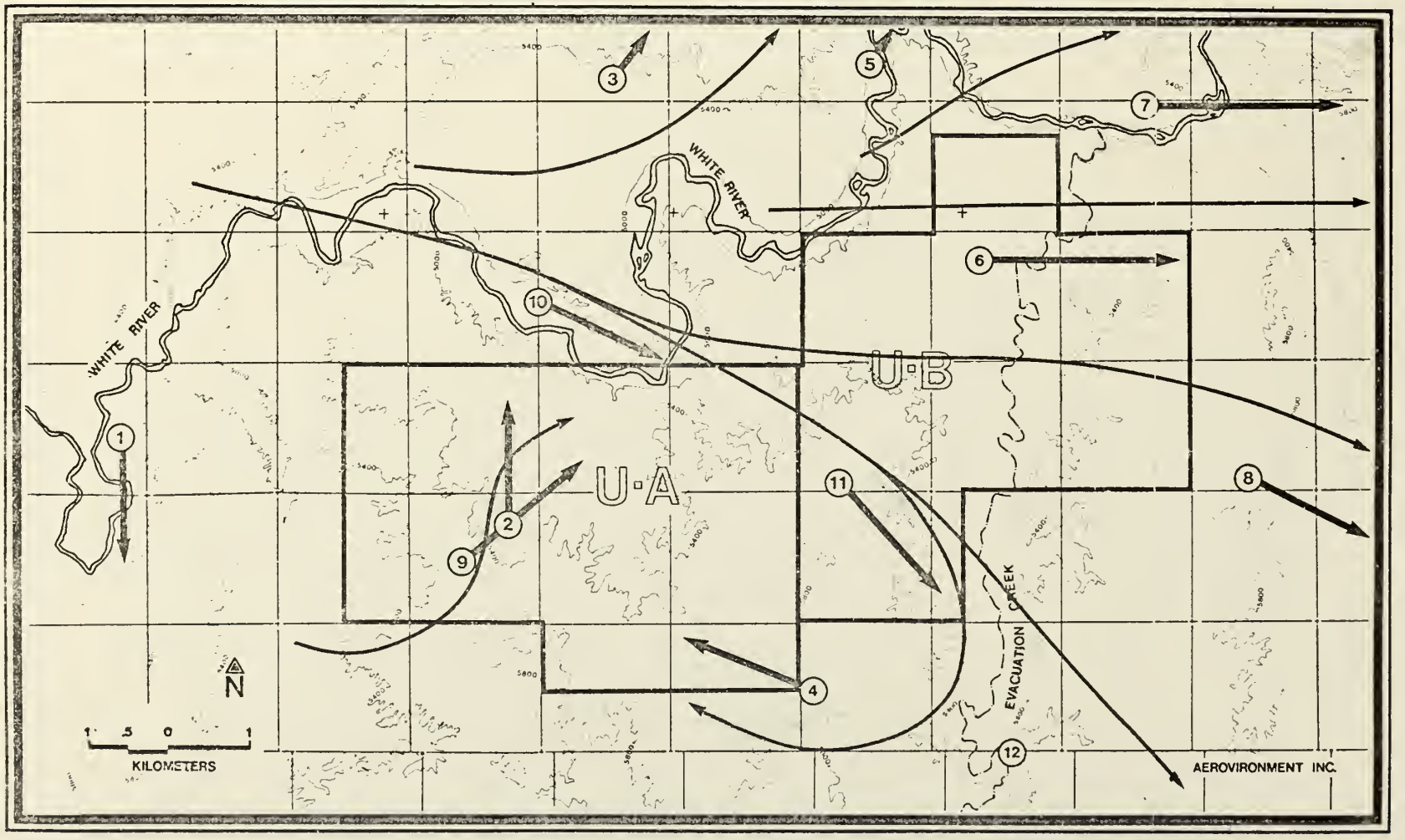


FIGURE III-6. TYPICAL AFTERNOON SURFACE AIRFLOW PATTERN ON THE TRACTS IN FALL.

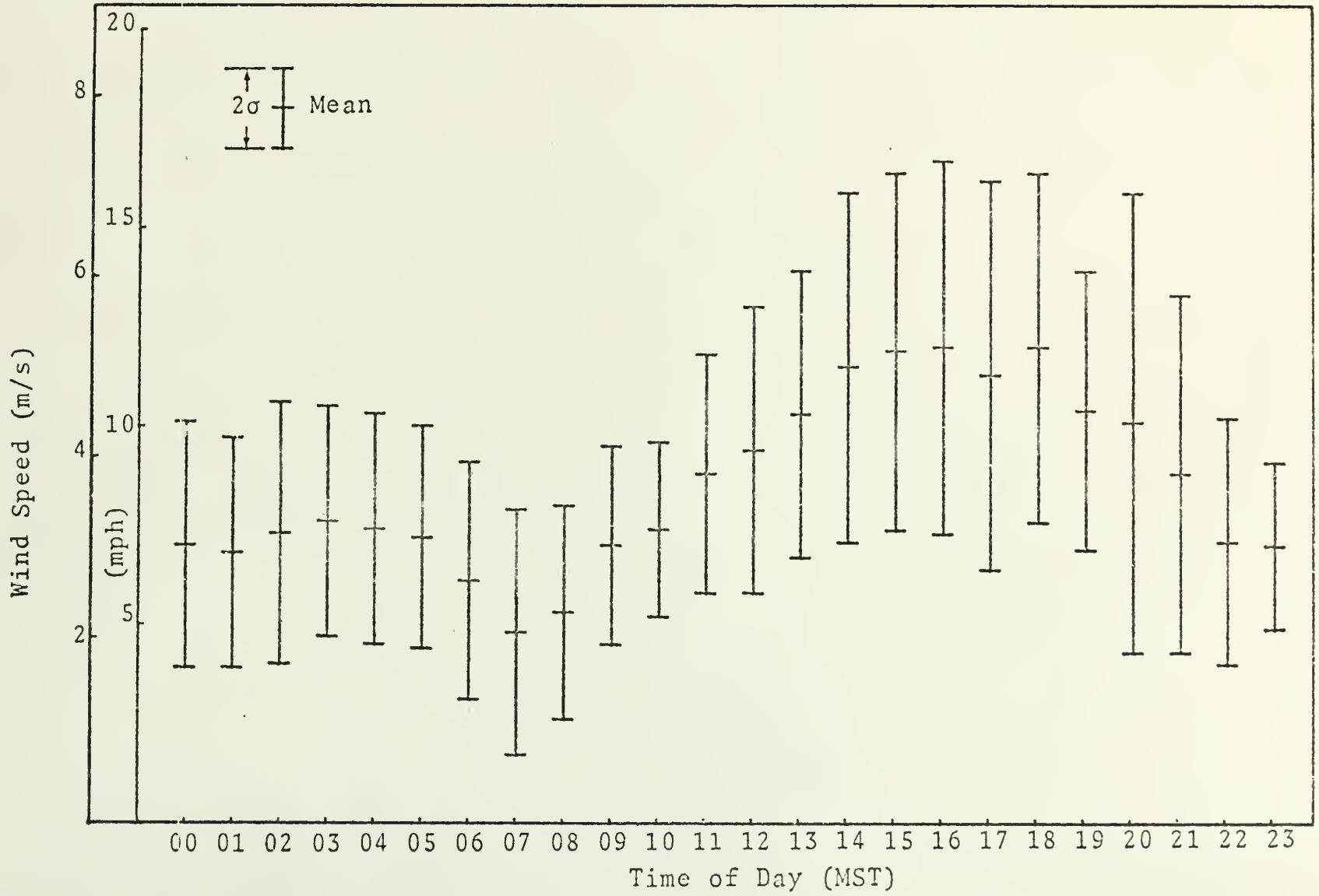


FIGURE III-7. DIURNAL VARIATION OF MEAN WIND SPEEDS AND THEIR STANDARD DEVIATIONS AT STATION A-6 IN JULY.
This pattern is representative of the entire year except for the winter months.

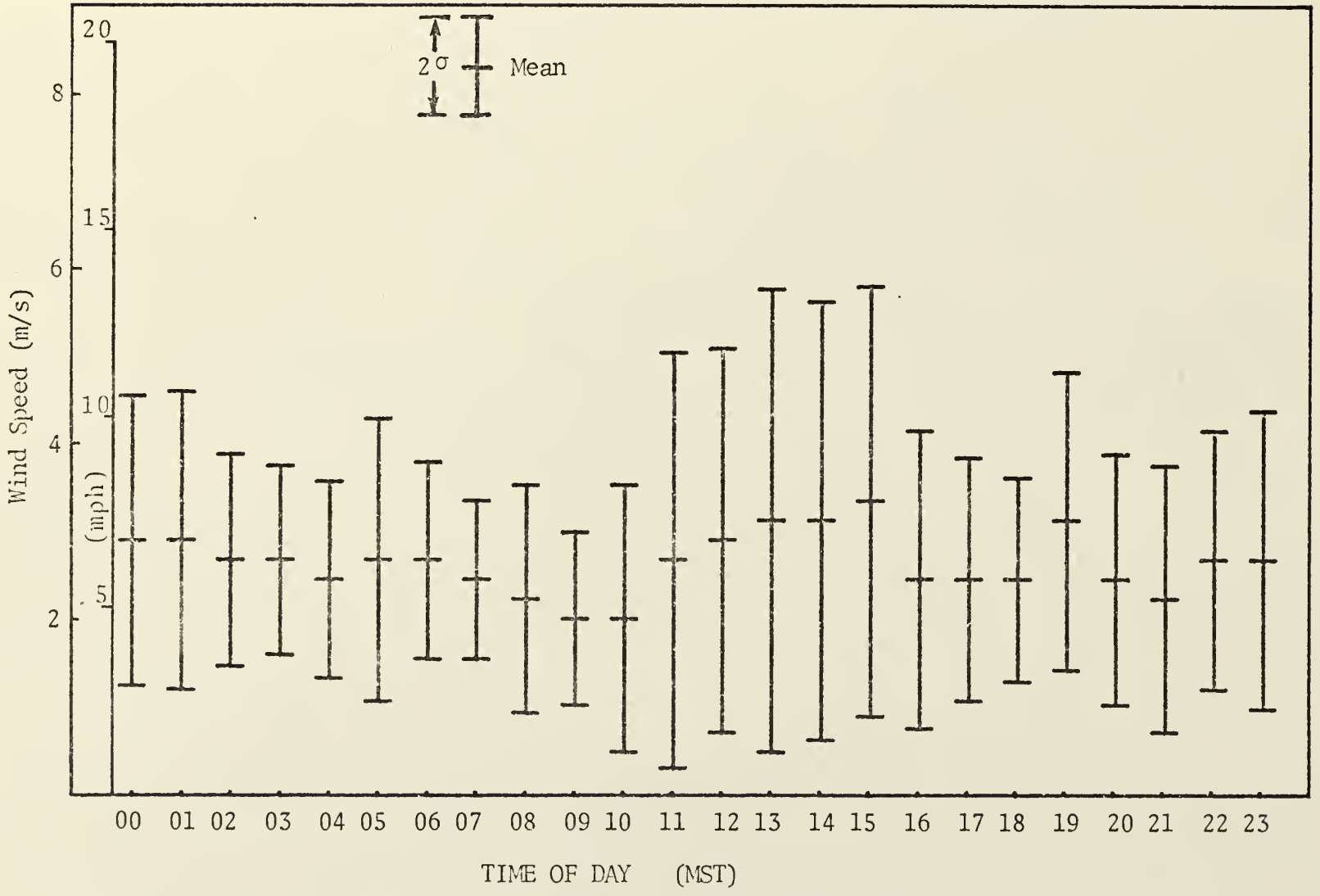


FIGURE III-8. DIURNAL VARIATION OF MEAN WIND SPEEDS AND THEIR STANDARD DEVIATIONS AT STATION A-6 IN JANUARY 1975, A TYPICAL WINTER MONTH.

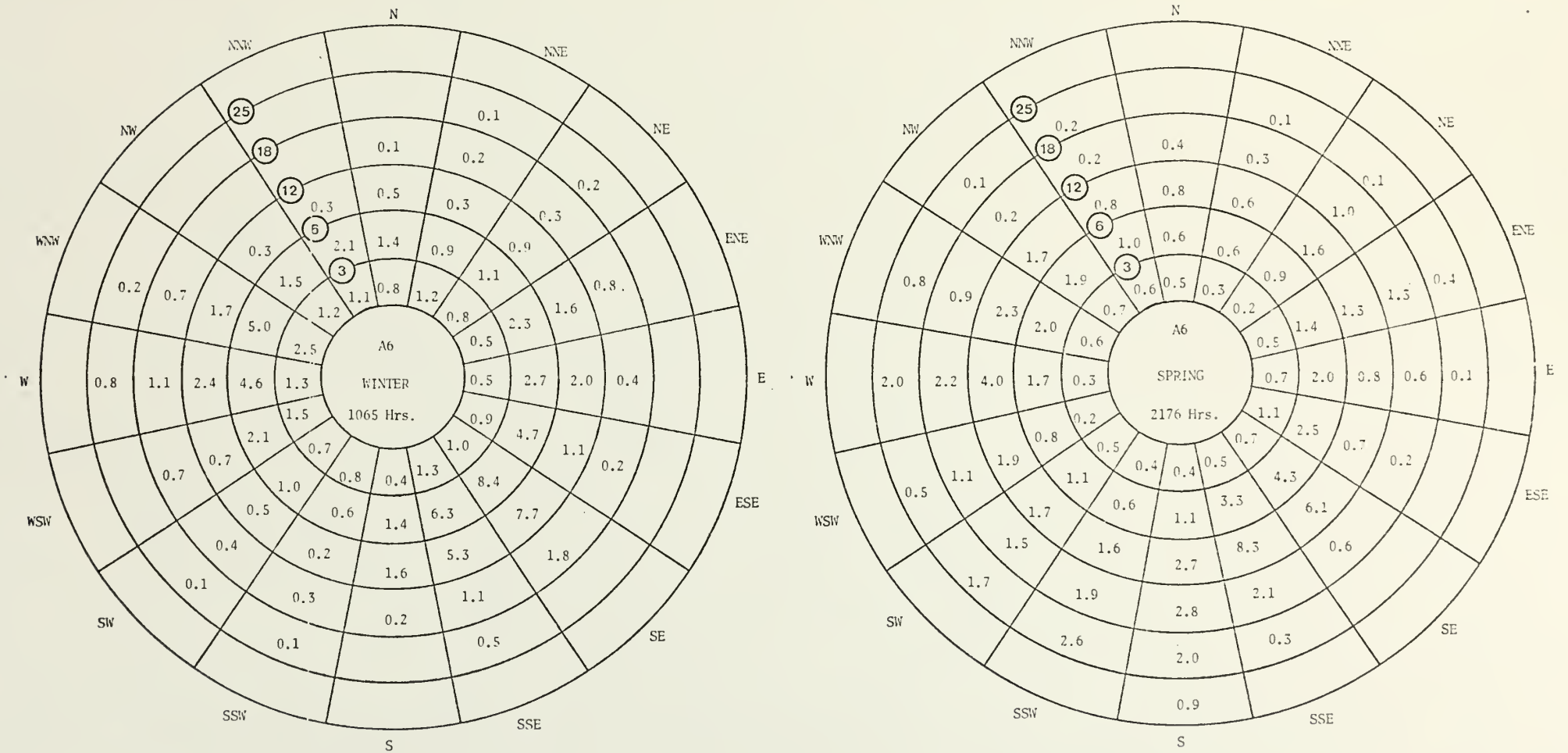


FIGURE III-9. RELATIVE FREQUENCY DISTRIBUTION (%) OF WIND SPEED AND DIRECTION AT STATION A-6 IN ALL FOUR SEASONS.
Circled numbers are wind speed readings in mph (multiply by 0.44 to get speeds in m/s).

During the entire measurement period, low winds were usually observed at night and in early morning, especially between 0600-0900 MST, and strong winds were generally observed between 1300-1700 MST. Wind speeds over the ridges and widely exposed terrain were usually much higher than wind speeds in the protected valleys.

The winter season had the most low winds and the least high winds. Since the dispersion of windborne effluents is strongly correlated to the wind speed, i.e., strong winds enhance dispersion, winter will probably have the highest air pollution potential.

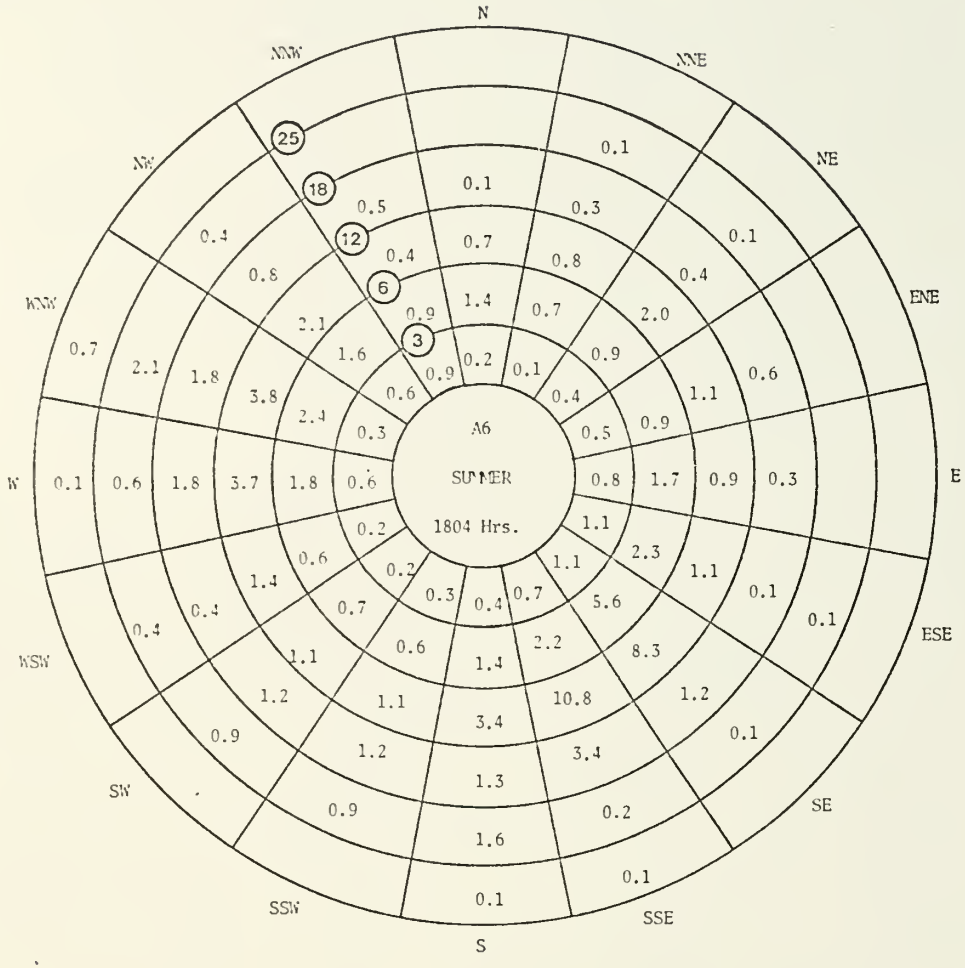
Figure III-10 gives the diurnal variation in temperature in February and July at Station A-6. These two months represent extremes in temperatures on the tracts: February had the lowest temperatures and July had the highest temperatures. The average afternoon temperatures in July and February were 30°C (86°F) and -1 C° (30°F), respectively; the average morning temperatures in July and February were 17°C (63°F) and -9°C (16°F), respectively. A strong similarity in the diurnal patterns and in the magnitudes of the diurnal differences exists for all the other months. The daily maximum temperature was usually observed at 1400-1500 MST, and the daily minimum temperature was observed at 0500-0600 MST. Spatial variations in temperature are evident on the tracts, again attributable to topography. Station A-10, by the White River in a protected valley just north of Tract U-a, consistently registered a lower temperature reading.

d. Conclusions

The meteorology of the tract area during the past year, a typical year except for higher-than-normal atmospheric moisture, can be summarized as follows:

Surface wind flows were generally drainage flows at night from the higher terrain to the south of the tracts, and afternoon flows were from the southwest. The flows were complicated by topography.

The lowest wind speeds usually occurred on winter mornings and the highest on spring afternoons. Low winds (below 1.3 m/s, or 3 mph) were most prevalent in winter and least frequent in fall; high winds (above 8 m/s, or 18 mph) were most prevalent in spring and almost non-existent in winter.



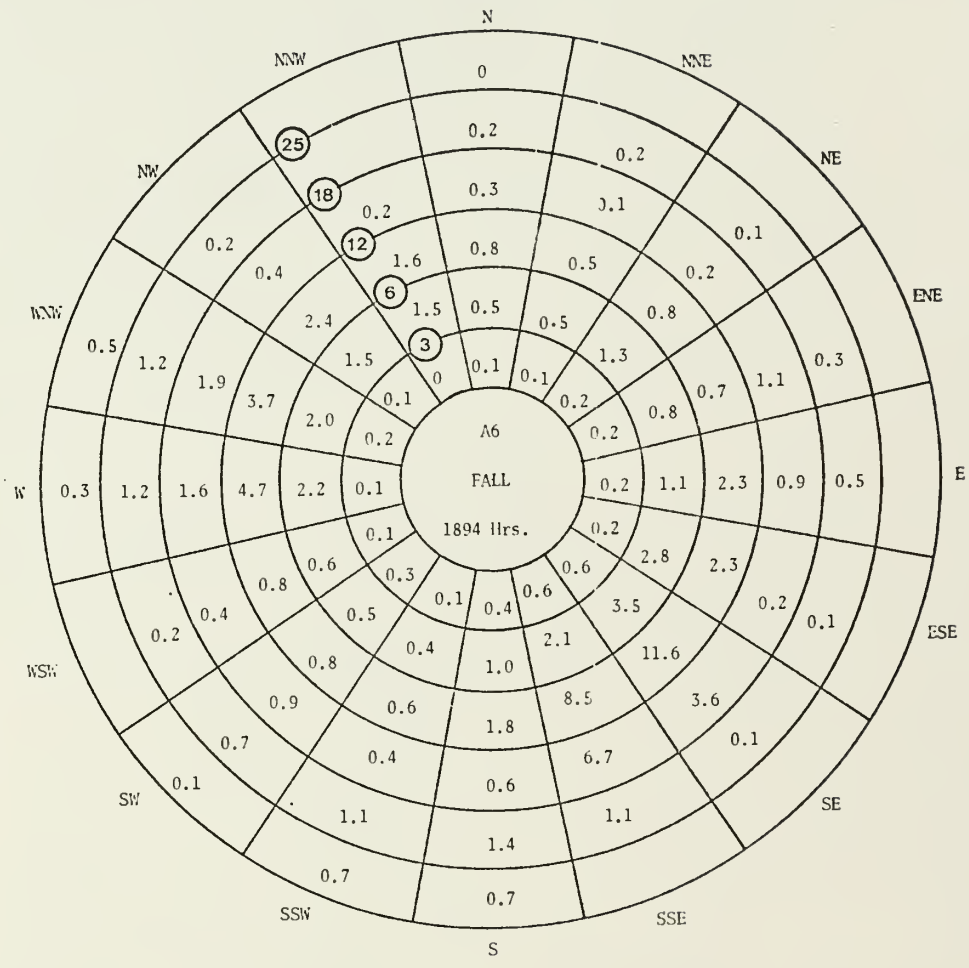


FIGURE III-9. (Continued)

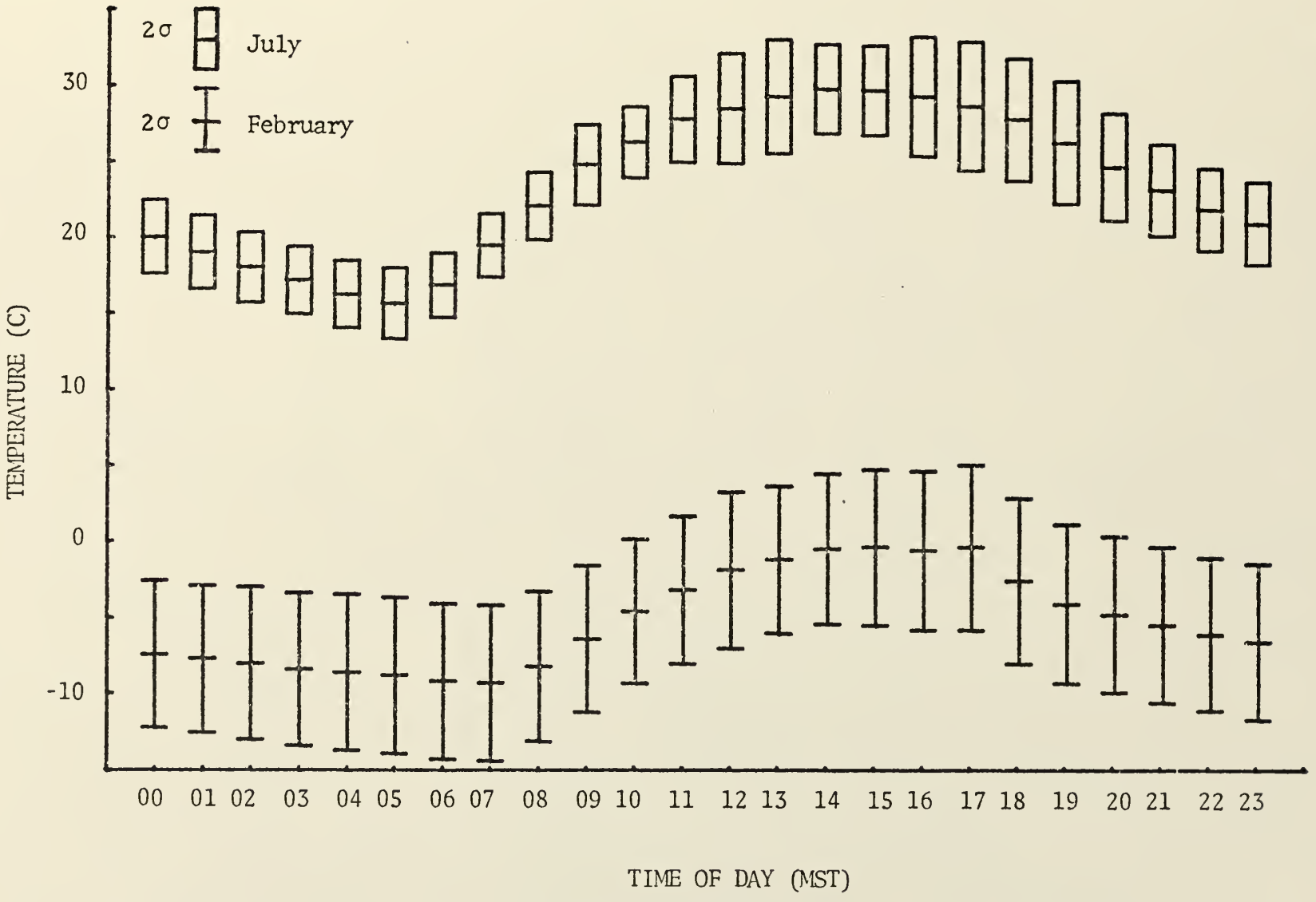


FIGURE III-10. DIURNAL VARIATION OF MEAN TEMPERATURES AND THEIR STANDARD DEVIATIONS AS STATION A-6 IN FEBRUARY AND JULY.

Temperatures ranged from an average low of -9°C (16°F) on February mornings to an average high of 30°C (86°F) on July afternoons. Again, there was a fair degree of spatial variability, especially in the mornings.

A surface-based inversion generally occurred in the morning. The inversions were deepest (409 m) in the fall and shallowest (243 m) in winter. The inversion generally lifted and disappeared by the afternoon, except in winter, when a strong elevated inversion often remained. An additional inversion aloft occurred frequently in fall and winter and usually persisted through the day.

These observations indicate that the impact of air-contaminant emissions from future developments in the tract area will be greatest in winter, which frequently has low winds and strong, moderately deep surface based inversions. Poor dispersion conditions will be less likely during the other seasons, either because of more winds or fewer inversions. Blowing dust will be more likely in the late spring, when high winds are common and the ground is dry. These subjects are discussed further in Section III.A.2.

e. Work Scheduled

The second year of meteorological baseline monitoring will be much like the first, except where the Area Oil Shale Supervisor approves modifications in the existing program. Such changes would improve the data base, particularly in the vicinity of the proposed plant facility, and would reduce energy consumption, cost, and data redundancy. The proposed changes include the deletion of the 20-m wind measurements at Stations A-2 and A-6; the deletion of anemometers at Stations A-1, A-5, A-9, and A-12; and the addition of an anemometer in the north side of Section 22 on Tract U-a in the general vicinity of the proposed plant site (Station A-13). Verifying the representativeness of the first-year data will be the main objective of second-year monitoring.

2. UPPER AIR METEOROLOGY

a. Objectives

Refer to Section III.A.1.a for a discussion of program objectives.

b. Methodology

Meteorological conditions above the fixed towers were measured at Station A-6 throughout the year by regularly scheduled rawinsonde launches and by continuous acoustic sounding of the lowest kilometer (0.6 mi) of the atmosphere. Rawinsonde balloons recorded temperature, relative humidity, and wind speed and direction from the surface to at least the 500 millibars (mb) pressure level (about 5,500 m, or 18,000 ft above mean sea level, and thus about 3,900 m or 13,000 ft above the tract surface). The balloons were launched twice every sixth day--the first within 1 hour of sunrise and the second at approximately 1400 MST. Balloons were also launched during special field experiments and midway between regular launch dates whenever high winds prevented launches at the regularly scheduled times.

The acoustic-sounding measurements were made continuously throughout the year by a monostatic acoustic sounder. Bistatic acoustic sounding supplemented the monostatic soundings at certain times of the year. The monostatic records displayed the atmospheric structure up to a height of 1 km above the surface and provided data on stability, temperature inversions, and thermal plumes in that region. The bistatic records indicated atmospheric turbulence between 200 m and 450 m (655 ft and 1,475 ft) above the surface. These records were used for the diffusivity description in Section III.B. Additional meteorological measurements were made during two intensive diffusion experiment periods in February and June 1975 (see Section III.B).

c. Summary of Results

The upper air measurements by rawinsonde and acoustic sounding indicated that during the entire study period a surface-based inversion attributable to nocturnal cooling of the earth's surface usually occurred in the morning and usually disappeared in the afternoon. The average thickness of the morning surface-based inversion increased from about 243 m in winter to 253 m in spring and from 362 m in summer and to 409 m in fall. The strength of the inversion in winter, spring, and fall was about 2°C/100 m. The strength of the inversion in summer was much weaker, averaging 1°C/100 m.

Relative humidity in the lower kilometer above ground level (AGL) was about 70 percent in the morning and about 50 percent in the afternoon from winter to spring. In summer the relative humidity in the lower kilometer had decreased

to about 50 percent in the morning and to about 30 percent in the afternoon. In fall it was about 40 percent in the morning and about 35 percent in the afternoon.

Winds in the first kilometer above the ground were variable from day to day, whereas above the first kilometer the winds were usually from the west with an average speed of about 8 m/s (18 mph) during winter and spring and about 4 m/s (9 mph) in summer and fall.

The results of two typical rawinsonde soundings (June 11, 1975) are given in Figures III-11 and III-12. In the morning, a surface-based inversion extended to 114 m AGL and was topped by a stable layer about 1,000 m thick. Above this was a slightly stable to neutral layer. Humidity in the first 2 km was around 70 percent. Winds were from the southwest at about 1 m/s (2 mph) in the first kilometer and from the west to the northwest at about 3 m/s (7 mph) in the second kilometer. The afternoon sounding showed a super-adiabatic layer of about 26 m deep at ground level. The rest of the atmosphere was neutral or slightly stable. It was dry in the afternoon, with approximately 40 percent humidity throughout the lower atmosphere. Winds came from the same directions as in the morning, with stronger winds (~3 m/s) in the first kilometer.

For comparison, a representative monostatic acoustic-sounder record with rawinsonde-derived temperature profiles superimposed* is given in Figure III-13. The typical growth and decay of the surface-based inversion is shown clearly on this continuous record. The acoustic radar chart shows a surface-based inversion in the morning. The top was about 200 m AGL, and the inversion strength changed at about 100 m AGL. The thickness of the inversion decreased until 1000 MST and then increased steadily. This is contrary to normal diurnal variations and was caused by the approach of a low-pressure system. (The barometric pressure started falling at 0900 MST.) Roots of thermals were apparent starting at 1430 MST. The activities of these thermals destroyed the lower part of the inversion so that by 1800 MST only a very shallow upper-air inversion was left.

The temperature soundings the same morning indicated a surface-based inversion 196 m thick with a strength of 1.8°C/100 m. Its thickness increased to 286 m and its strength to 3.1°C/100 m by mid-day. By 1800 MST the

*These data were collected during one of the special diffusion case-study experiments described in Section III.B. (There were three rawinsonde launches that day.)

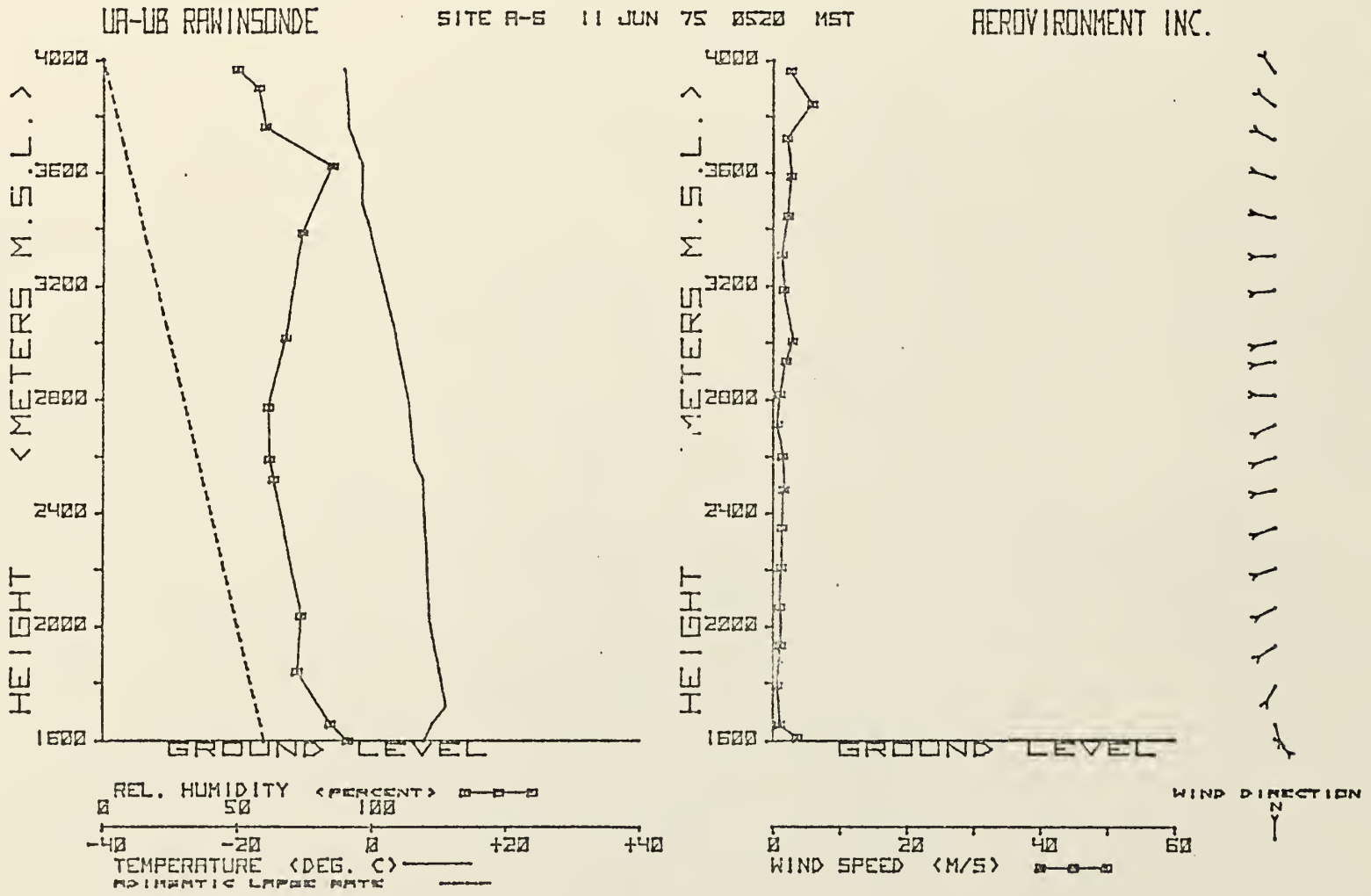


FIGURE III-11. RAWINSONDE SOUNDING AT 0520 MST ON 11 JUNE AT STATION A-6.

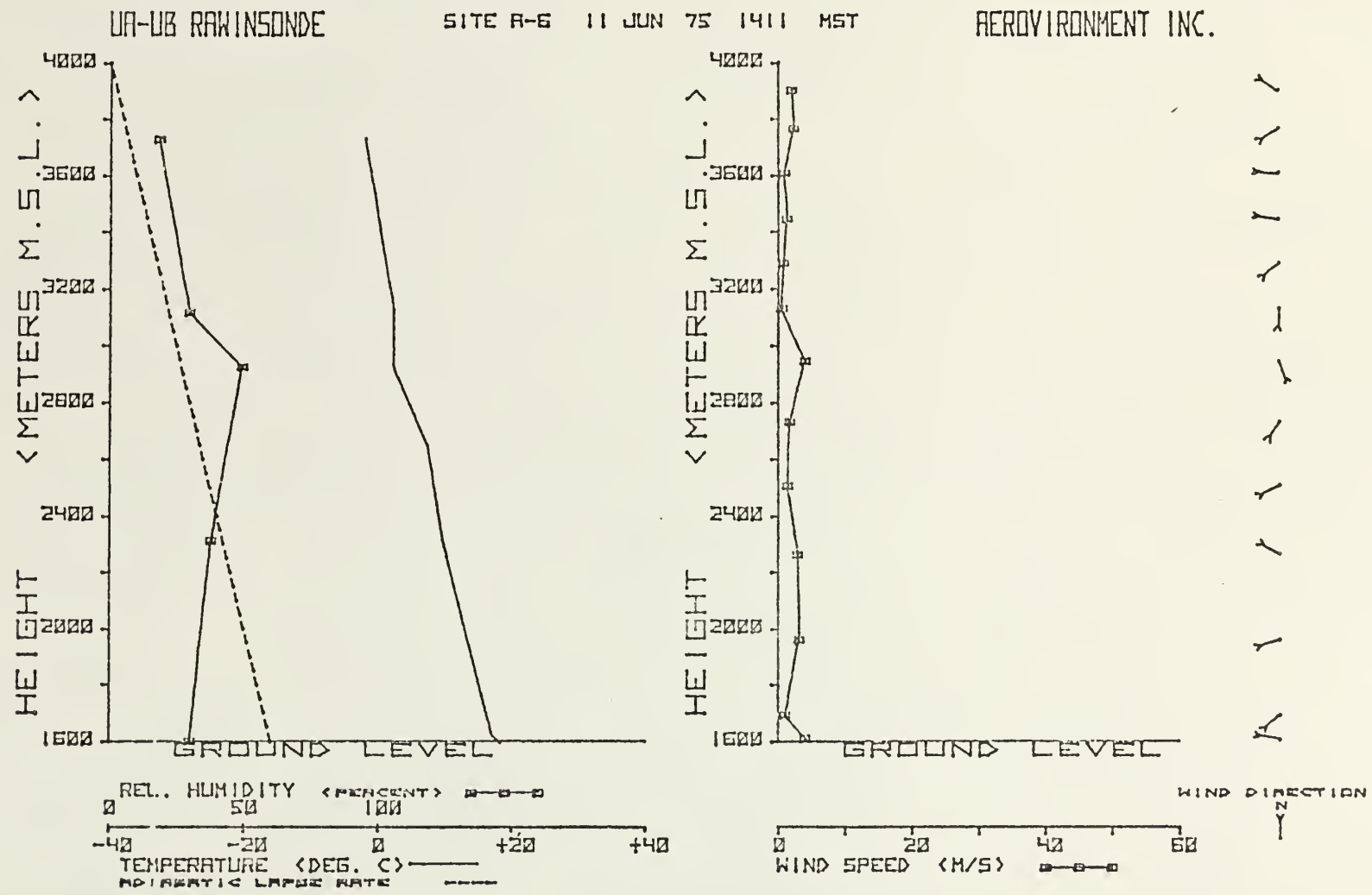


FIGURE III-12. RAWINSONDE SOUNDING AT 1411 MST ON 11 JUNE AT STATION A-6.

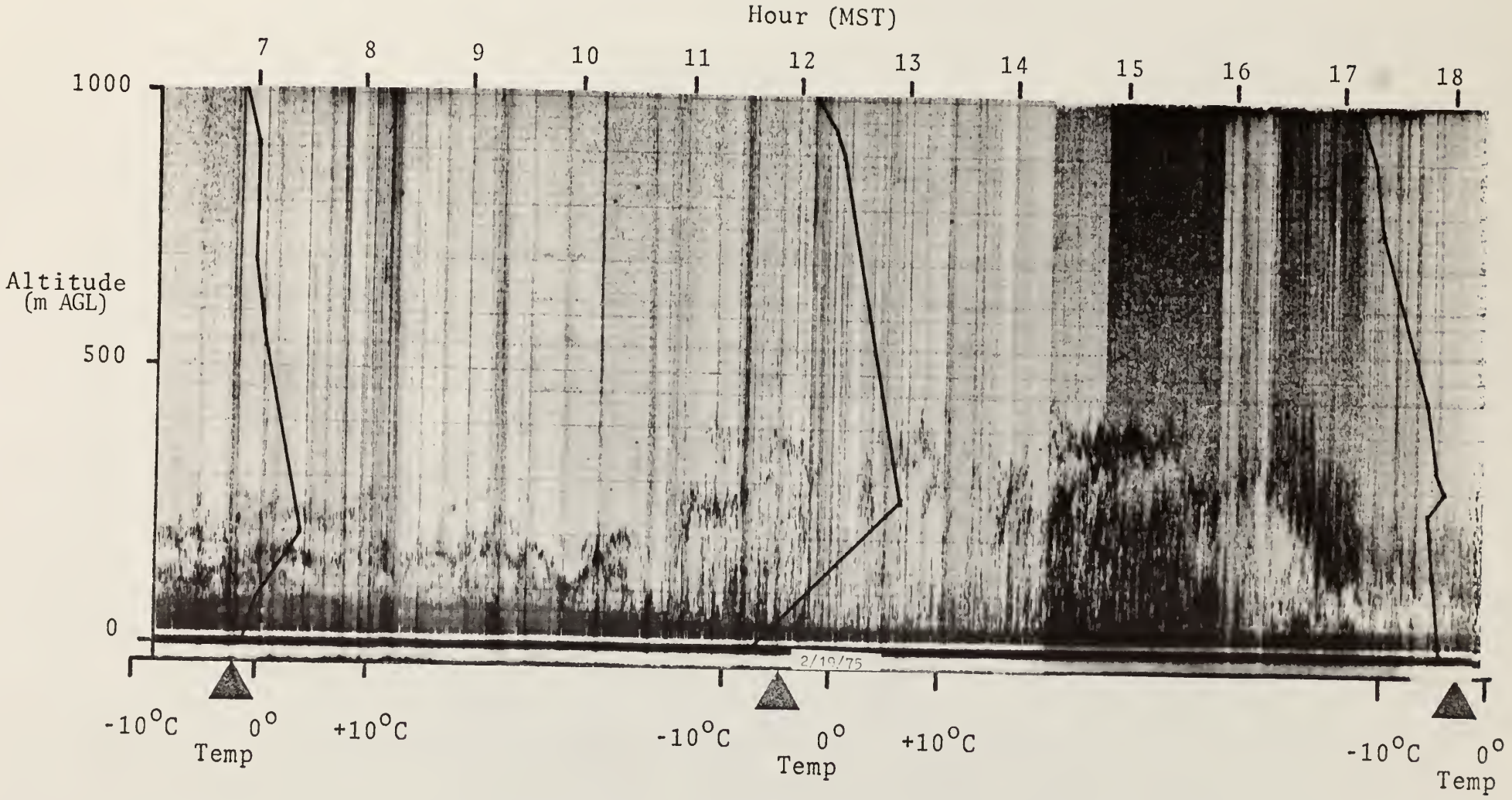


FIGURE III-13. ACOUSTIC RADAR RECORD FOR 19 FEBRUARY 1975, WITH RAWINSONDE TEMPERATURE SOUNDINGS SUPERIMPOSED.
Times of soundings are indicated by the triangles. The relatively horizontal dark layers are regions of stable stratification or inversions; the vertical spikes in the afternoon are the bases of thermal plumes, and denote unstable atmospheric conditions.

inversion had been weakened to a shallow upper-air inversion 59 m thick with a base at 250 m AGL.

The soundings shown in Figures III-11 through III-13 are representative of the types of conditions observed throughout the year. The changes from season to season are in the strength and thickness of the inversion, as noted previously, rather than in fundamental changes in meteorological patterns.

To verify the representativeness of the first-year data, certain meteorological parameters were compared with historical norms. Because of the lack of historical meteorological data on the tracts, the test of whether or not the meteorological conditions during the period of measurements were normal was based on rawinsonde data collected by the National Weather Service at Grand Junction, the closest upper-air monitoring station. Although the station is far from the tract area, such a test is still a valid indication of the normality of the synoptic-scale characteristics of the meteorology for this period, because Grand Junction and the tracts share the same upper air mass. Average monthly wind speed, temperature, and humidity readings over ten years (1964-1973) were calculated for standard significant pressure levels--the surface (1,480 m, or 4,850 ft), 850 mb (also approximately at the surface in Grand Junction), 700 mb (about 3,000 m, or 10,000 ft), 500 mb (about 5,600 m, or 18,300 ft)--at both 00Z (1700 MST) and 12Z (0500 MST). These data were then compared with corresponding averages for the same months from November 1974 through September 1975. Comparison with later months has not yet been possible because of the six-month delay between upper-air data collection at Grand Junction and public release of these data.

Detailed discussions of these comparisons were presented in the third, fourth, and fifth quarterly reports. Table III-3 summarizes the results of the comparison for the 700-mb level, the first standard level above all of the terrain in the Grand Junction and the tract areas. As seen in the summary, this eleven-month period has had average winds and temperatures and much higher than normal humidity. At no time has the humidity been less than normal; humidity from February through May was usually more than 10 percent (relative humidity units) above the norm, and sometimes 20 percent above. The only other significant seasonal deviation was the low winds during November and December 1974, which were approximately 30 percent lower than normal but which were followed by higher than normal winds in January through April and in August 1975. Temperatures were consistently normal in all months. The baseline meteorological measurements made so far have indicated a relatively average year in all parameters except humidity.

TABLE III-3

UPPER AIR DATA

Comparison of 700 mb monthly average upper air data at Grand Junction, Colorado from November 1974 through August 1975 with their corresponding ten year means. Deviations from the norm are expressed in percent of the norm for wind speed, in degrees C for temperature, and in percent relative humidity for relative humidity.

Month	Afternoon (00Z) Soundings						Morning (12Z) Soundings					
	Wind Speed (m/s)		Temp (C)		Rel. Hum. (%)		Wind Speed (m/s)		Temp (C)		Rel. Hum. (%)	
	Norm	% Dev	Norm	Dev	Norm	Dev	Norm	% Dev	Norm	Dev	Norm	Dev
Nov 74	5.0	-34	-2.4	-0.5	51	3	5.1	-27	-3.4	-0.7	57	4
Dec 74	5.6	-32	-6.2	-1.6	54	2	5.7	-39	-7.0	-1.7	62	2
Jan 75	5.6	14	-6.7	-0.3	52	3	5.9	12	-7.4	-0.7	57	3
Feb	3.9	26	-6.4	-1.4	50	8	4.2	17	-7.6	-1.0	57	13
Mar	5.0	-12	-3.8	-1.2	46	13	4.5	29	-5.4	-1.3	55	12
Apr	5.2	17	-0.1	-2.0	42	5	5.1	33	-2.2	-2.7	50	11
May	4.5	7	5.1	-1.7	34	-3	4.0	13	3.6	-2.6	45	11
June	4.8	17	10.9	-1.5	33	4	4.3	9	8.5	-1.5	40	0
July	2.7	-41	15.2	-0.3	31	6	3.0	-33	13.0	-0.5	40	6
Aug	2.6	46	14.0	-0.5	34	-3	3.1	26	11.6	-0.3	46	-9
Sept	4.5	-42	9.2	0.7	36	-3	4.4	-43	7.0	0.5	45	-5
11-Mo Avg.	4.4	-7	2.9	-0.9	42	3	4.5	-7	1.0	-1.1	50	5

SOURCE: Summary of Constant Pressure Data, WBAN 33, Environmental Data Service of the National Climatic Center.

d. Conclusions

Refer to Section III.A.1.d for a discussion of conclusions.

e. Work Scheduled

Some program adjustments approved by the Area Oil Shale Office (AOSO) were implemented February 1, 1976. These adjustments include elimination of further upper air measurements by either rawinsonde soundings or by acoustic radar, since the upper atmosphere conditions appear to be adequately defined. Upper-air data will be further analyzed for the Detailed Development Plan during the second year.

B. DIFFUSIVITY

Practically nothing was known about diffusion potential in the region of the oil shale tracts prior to the monitoring program. No mesoscale meteorological data was available for the Uinta Basin.

1. OBJECTIVES

One of the implied objectives of the baseline measurement program was to determine the ability of the atmosphere in the study area to dissipate the air pollution that would result from development on and around the tracts; more specifically, the objective was to define the meteorological factors that might influence the transport, diffusion, and (possibly) chemistry of pollutants that could be emitted by sources on and around the tracts. This is best summarized in terms of the diffusivity of the atmosphere, i.e., in terms of the ambient turbulence that occurs and the scales appropriate for diffusing materials in the atmosphere.

Diffusivity characterization is necessary for designing environmentally sound mining and oil shale processing facilities and supporting developments around the tracts. Although not a baseline measurement activity per se, it was appropriate to measure diffusivity in close conjunction with the baseline program.

2. METHODOLOGY

The meteorological sensors described in Section III.A.2 were used for all of the continuing diffusivity measurements. Because of their relationship to pollution disperions the parameters of greatest interest were wind speed and direction, lapse rate of temperature, and lateral and vertical turbulence (σ_θ and σ_w, respectively). A secondary measurement of interest was that of net radiation, an indication of whether the atmosphere was tending toward stability (upward radiation flux) or instability (downward radiation flux). The acoustic radar displayed dispersion-related factors directly in both the monostatic and bistatic modes, giving a continuous picture of the diurnal evolution of the diffusivity of the atmosphere.

The meteorological data for the diffusivity characterization were analyzed differently from the data for the meteorological description. For the diffusivity study, joint distributions of wind speed and factors limiting mixing (such as stable lapse rates, inversions, or low turbulence levels) were more important. Some of the results of these analyses are discussed in the following summary.

To supplement the continuous measurements and to provide more detailed data on diffusive conditions aloft, two special experiments were performed in February and June 1975. During these experiments detailed profiles of the turbulence and wind structure aloft were obtained by aircraft-borne and balloon-borne sensors, and the actual diffusion of smoke plumes released from 90 m (300 ft) above the ground was measured by aircraft probing of the plume. The February experiment is described in detail in the third quarterly report and the June experiment is described in the fourth quarterly report. These descriptions will not be repeated here, although results are given in the following summary.

3. SUMMARY OF RESULTS

The dispersion or dilution of windborne effluents in the atmospheric boundary layer is very dependent on the turbulence intensity or the diffusivity of the atmosphere. Diffusivity can be defined by direct measurements of turbulence and by indirect inference of turbulence from other measures related to atmospheric mixing. An indirect method of estimating diffusivity is by temperature soundings, which can be used to describe the vertical stability of the atmosphere. Once the stability is described the numerical values of dispersion parameters can be estimated from experimentally derived stability/diffusion correlation curves.

A general description of typical atmospheric stability conditions was presented in the meteorology section, where it was noted that early morning surface-based inversions were common throughout the year. They usually disappeared in the afternoon, except during winter when the intense morning inversion strengths of 4°C/100 m could not be dissipated during the day. During the other seasons, neutral stability was generally observed near the surface in the afternoons. In addition, upper-air inversions were frequently observed in fall and winter and often persisted throughout the day. Thus, vertical mixing of material in the atmosphere is typically limited in the morning by surface-based inversions and is usually unlimited in the afternoon, except during winter. Because of this, conditions adverse to air pollution diffusion near the surface are most prevalent in winter.

To supplement the rawinsonde data at low altitudes, average temperatures and their standard deviations at Stations A-2, A-4, and A-6 at 0500 MST and 1400 MST in each season were plotted against the station elevations to give a seasonal "sounding" of temperature near the surface. These sounding profiles, which correlate well with the rawinsonde data, are given in Figures III-14 through III-17. The seasonal average temperature at Station A-4 was always higher than at A-2 and A-6 at 0500 MST, indicating surface-based inversions. The inversion strength, represented by the temperature increase from Station A-6 to Station A-4, was strongest in winter. An inversion also occurred in the afternoons during winter. During the other seasons, an isothermal or slightly stable temperature lapse rate was common in the afternoon.

Estimating atmospheric diffusivity by temperature soundings is, at best, qualitative in the complex topography conditions of the tract area; therefore, special experiments were conducted, once in winter (February 19 through 21, 1975) and once in summer (June 19 through 23, 1975), to describe diffusivity quantitatively for a few intensively studied days to assess the applicability of common diffusion estimation methods in the study area. Since these experiments--which involved direct measurements of stability, turbulence, and diffusion in the vicinity of Station A-6 and also, in the summer only, at Station A-11--were discussed in detail and their results documented in the third and fourth quarterly reports, only a brief summary of key results is presented here.

One portion of the experiment involved releasing a cloud of smoke from 90 m (300 ft) above the ground, as shown in Figure III-18, and tracking the cloud by instrumentation in a probing aircraft. These tests showed that the calmest

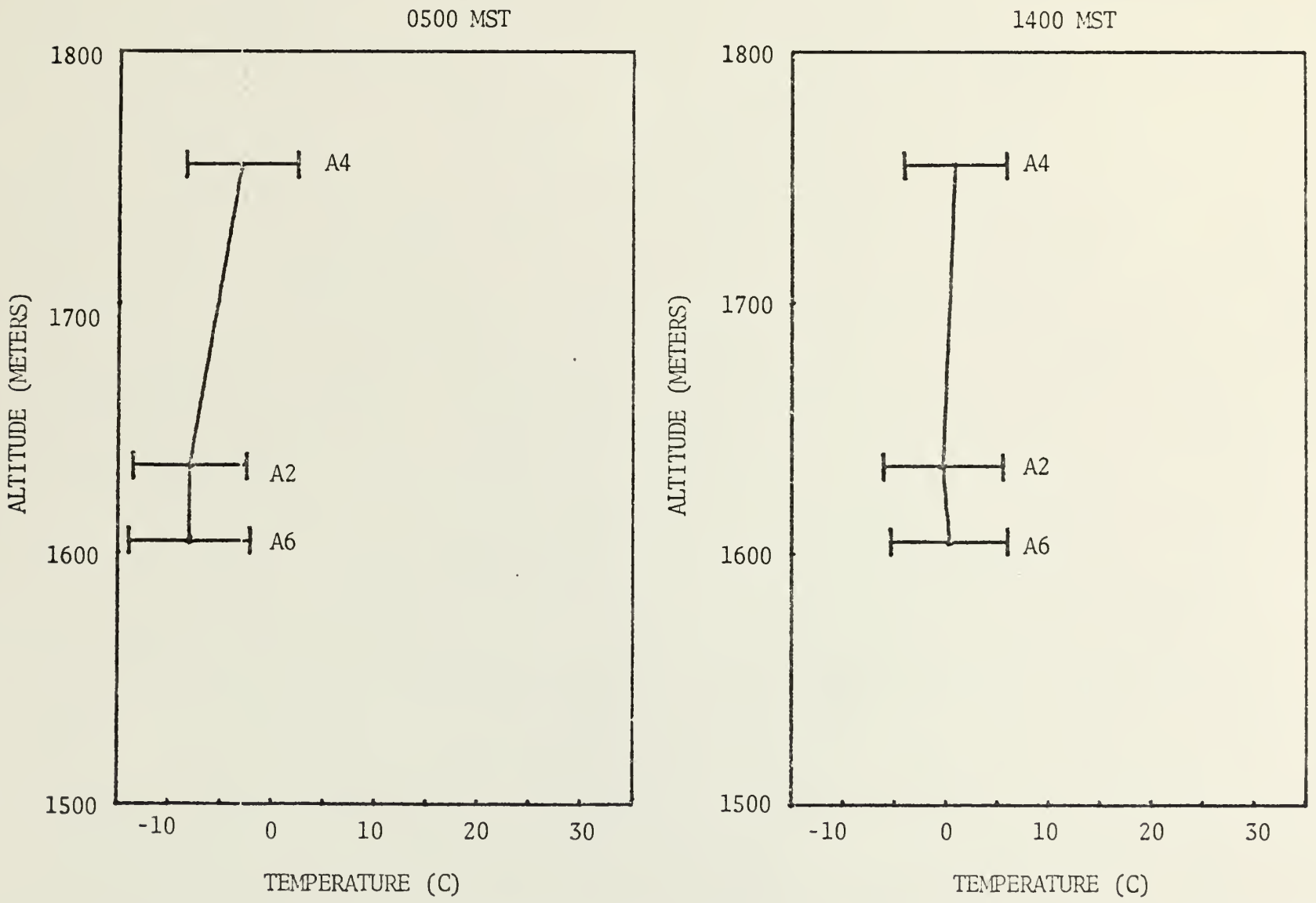


FIGURE III-14. AVERAGE WINTER TEMPERATURES (0500 AND 1400 MST) AND STANDARD DEVIATIONS AS FUNCTIONS OF STATION ELEVATION.

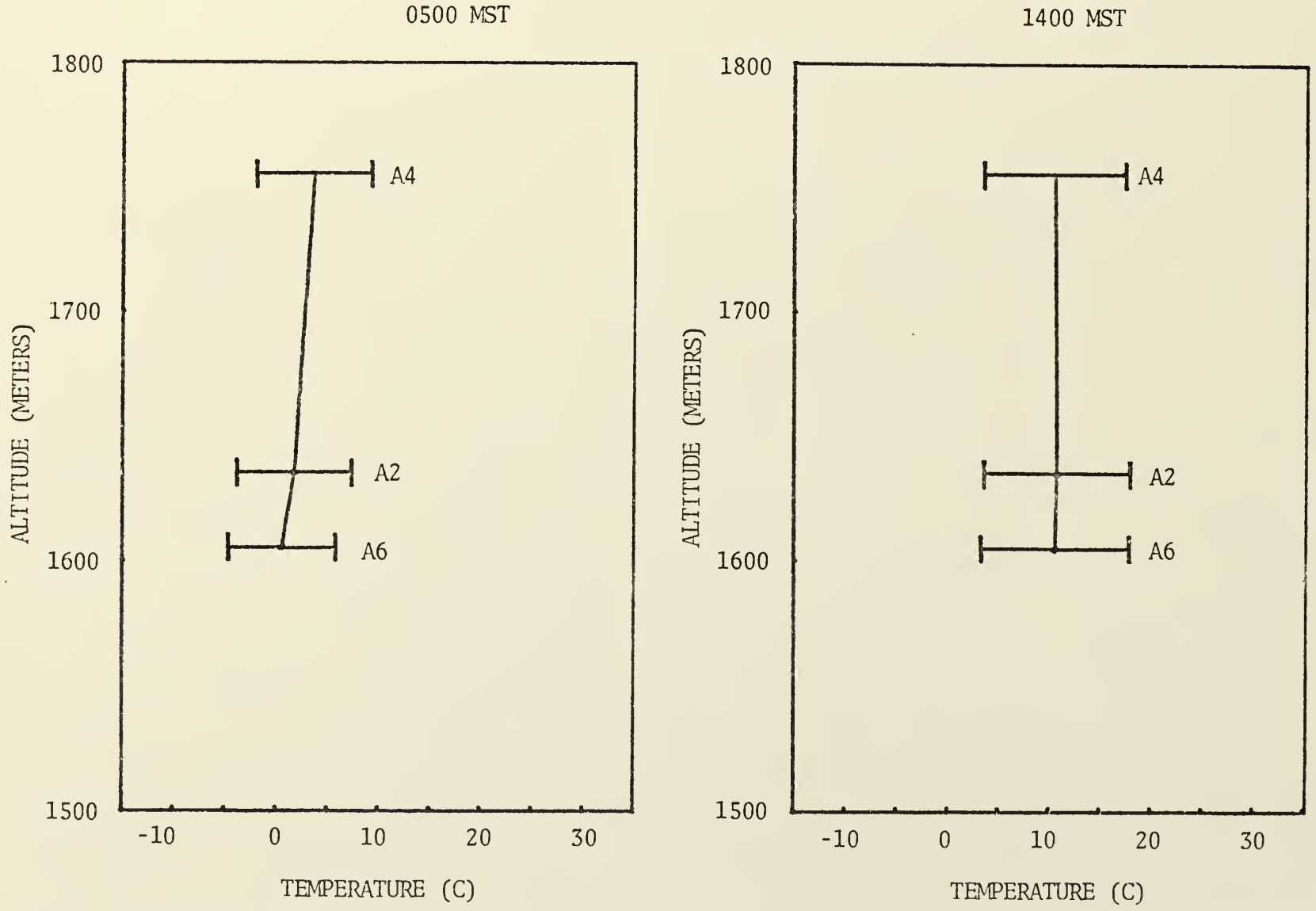


FIGURE III-15. AVERAGE SPRING TEMPERATURES (0500 AND 1400 MST) AND STANDARD DEVIATIONS AS FUNCTIONS OF STATION ELEVATION.

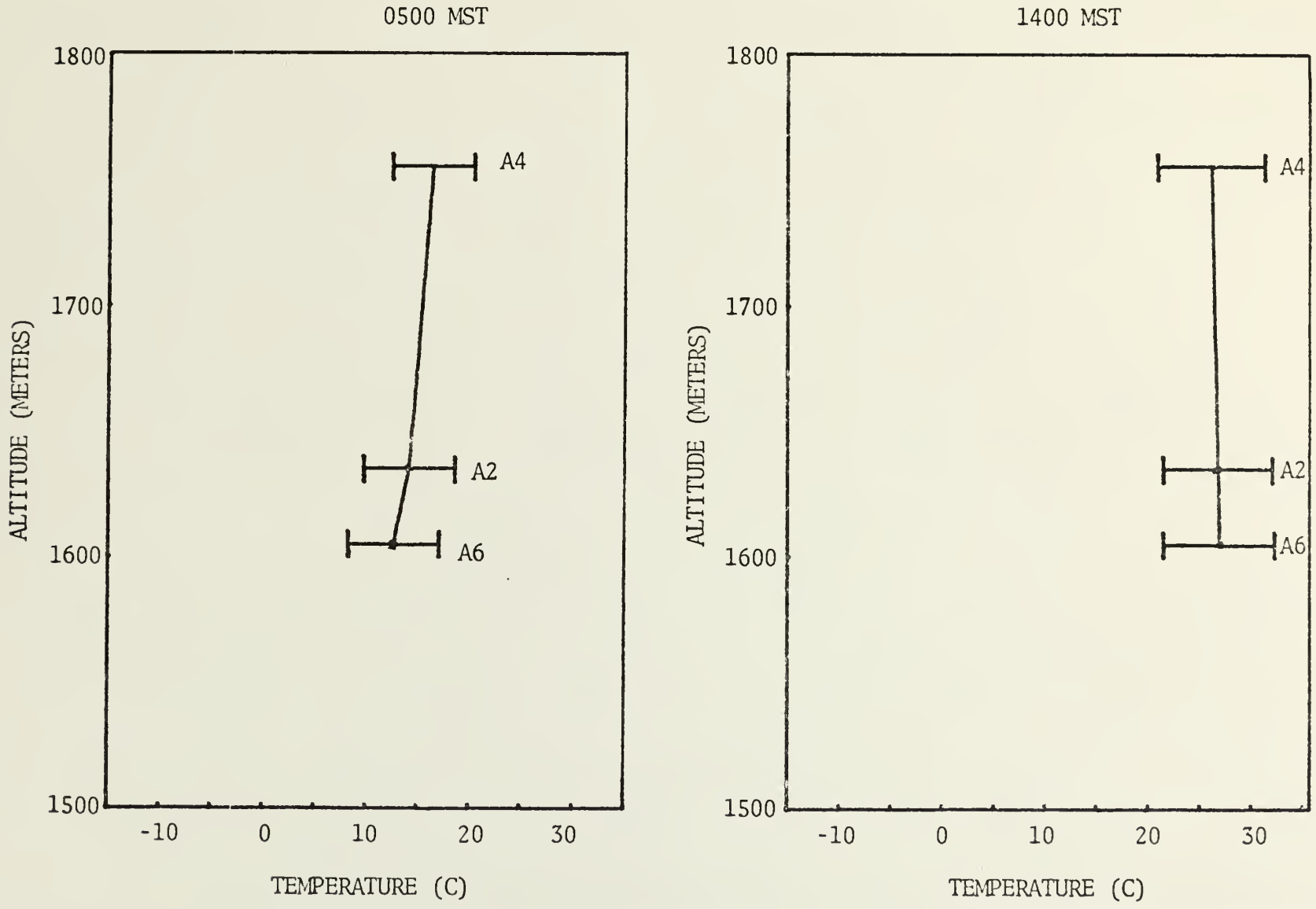


FIGURE III-16. AVERAGE SUMMER TEMPERATURES (0500 AND 1400 MST) AND STANDARD DEVIATIONS AS FUNCTIONS OF STATION ELEVATION.

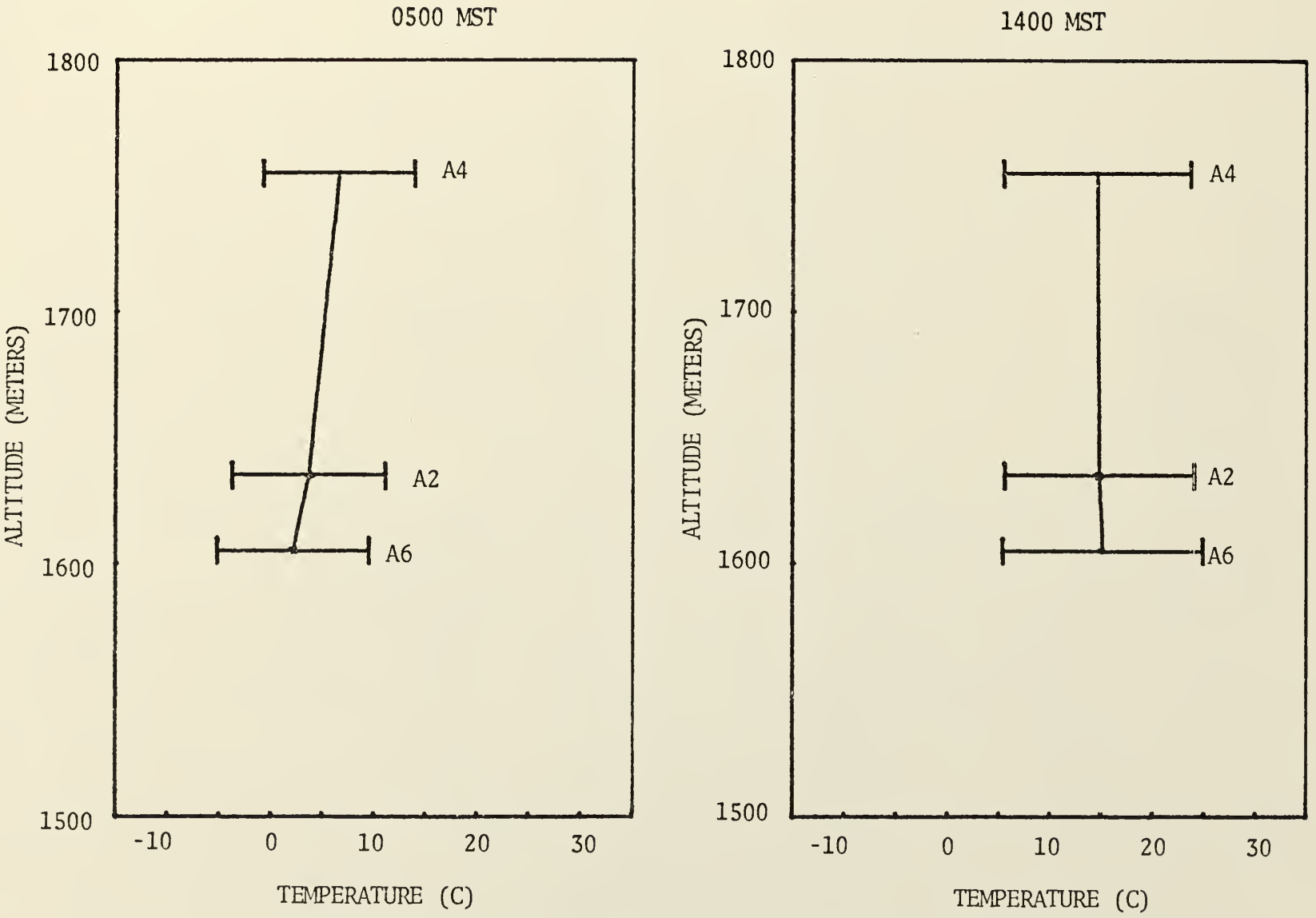


FIGURE III-17. AVERAGE FALL TEMPERATURES (0500 AND 1400 MST) AND STANDARD DEVIATIONS AS FUNCTIONS OF STATION ELEVATION.

conditions and the longest-lived smoke clouds usually occurred in the mornings in both winter and summer and in the evenings in winter; noontime conditions seldom allowed tracking for more than a few minutes and were often so windy that the balloons holding the smoke canisters could not be launched at all. All of the clouds studied remained at a relatively constant altitude or rose as they traveled. The exception was one cloud, which descended into Evacuation Creek from its release point at Station A-11. This one cloud was also the only one released at noon that had a significant lifetime.

Table III-4 compares the smoke cloud widths (σ) measured by the aircraft with those computed from the simple diffusion formula for the inertial subrange of turbulent eddy sizes,

$$\sigma = C(\varepsilon^{1/3} t^{3/2}, *$$

where C is a dimensionless coefficient of order unity, $\varepsilon^{1/3}$ is the magnitude of the ambient turbulence (which was measured by the aircraft), and t is the age of the cloud. The magnitude of C is not known, but previous experiments have shown a value near unity has yielded reasonable agreement with experimental data. Here the best correspondence between measured and computed values was found for $C \approx 0.5$, in which case the root-mean-square error in the computed values is less than 44 percent of the measured values. Because of this degree of correlation, which is quite satisfactory for cloud traveling at relatively low levels over complex terrain, it is probable that diffusion in the tract area can be reasonably estimated from measured turbulence values by relatively simple formulas, possibly with empirically calibrated constants.

The diffusion formula given was appropriate in form for relating the spread of the smoke cloud to the diffusing turbulence in the inertial subrange. Diffusion studies are usually concerned with surface concentrations from a surface or elevated source, which requires somewhat different formulas based on the same concepts. In this study the diffusion of a continuous plume is well handled for operational purposes by the approach developed by MacCready et al. (1974), which relates $\varepsilon^{1/3}$ to σ_v (the r.m.s. lateral wind speed, $\sigma_v = \sigma_\theta U$, where U is the mean wind speed) and σ_w by a scale function and by some empirical relationships using concepts of anisotrophy and shears; it then relates σ_y and σ_z (the plume width and depth, respectively) to these quantities and the travel distance,

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*This equation applies to a spherically diffusing cloud, which is appropriate here. The formula for a plume is slightly different.

FIGURE III-18. A SMOKE CLOUD EXPERIMENT.
Smoke plume emitted from smoke grenades supported 90 m above the surface by tethered balloons at Station A-6 during calm conditions at 0820 on the morning of 21 February. An instrumented aircraft is probing the plume at the center of the photograph. (The wide-angle lens used for this photo distorts angles, thus the normally vertical 30 m tower at Station A-6 appears to lean to the left.)

TABLE III-4

COMPARISON OF MEASURED SMOKE CLOUDS WIDTHS (σ) WITH THOSE COMPUTED FROM MEASURED TURBULENCE VALUES ($\varepsilon^{1/3}$).

Date (1975)	Time (MST)	$\varepsilon^{1/3}$ ($cm^{2/3} s^{-1}$)	t (s)	σ(m) Computed (C=0.5)	Measured
2/19	1700	1.0	1700	345	450
2/21	0820	0.6	1700	165	100
6/19	0610	1.4	1000	260	220
6/20	0630	0.8	1000	115	160
6/21	0600	0.9	700	80	230

again with a scale function. The scale functions can be estimated from data given in the referenced paper. Finally, from the σ_y (x) and σ_z (x) values thus derived, χ/Q values can readily be computed from the standard formulas for Gaussian plumes.

The dispersion of a plume is often described mathematically by the diffusion equation having the following form,

$$\frac{\chi}{Q} = \frac{1}{\pi\sigma_y\sigma_z U} \exp\left(-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right),$$

where χ is the surface concentration; Q is the source emission rate; σ_y, σ_z are horizontal and vertical dispersion coefficients, respectively; U is the mean wind speed; and H is the effective stack height. MacCready et al. (1974) show that at downwind distances in excess of the order of a kilometer, $\sigma_z^2 \propto \sigma_w t$ where σ_v and σ_w are the root-mean-square turbulent fluctuations in the lateral wind speed v and the vertical wind speed w, and t is the time of plume travel. Using these relationships for H = 0 and noting that the location of a receptor is given by x = Ut, the following formula is derived:

$$\frac{\chi}{Q} \propto \frac{1}{(\sigma_v\sigma_w)^{1/2}x}$$

This relationship, with H taken as zero, is valid along the centerline of a plume released aloft or at the surface for emissions released also at the surface (although ground effect makes the constant of proportionality twice as great in the latter case as in the former). For other cases the decay in χ/Q with x is even greater because of the growth of σ_z in the exponential term of the full equation.

This equation shows the non-obvious results that χ/Q along the plume centerline does not depend explicitly on wind speed and that because of the rapid decay of σ_v with height, χ/Q on the centerline will increase strongly as the height of release increases.

This type of analysis is appropriate for estimating the surface impact of surface releases and the impact of elevated releases on isolated points of elevated terrain (where roughly the centerline concentration applies). For receptors off the plume centerline, the exponential term, which includes concentration delay with wind speed is:

$$\exp\left(-k\,\frac{H^2U}{\sigma_w\chi}\right)$$

Using this approach, a quantitative characterization of diffusivity on the tracts is possible, using the measurements of $\sigma_\theta = \sigma_V/U$) and of σ_W made continuously at Stations A-2, A-4, and A-6. Table III-5 presents the frequency distributions of the quantity $(\sigma_V\sigma_W)^{1/2}$, which is inversely proportional to χ/Q at any given receptor location, for four seasons of the year at Stations A-2 and A-6.

The data in Table III-5 demonstrate the following conclusions:

- The diffusion at Station A-6 is generally greater than that at Station A-2, which reflects the more sheltered location of Station A-2 in Southam Canyon.
- In contrast to the general situation, the highest diffusivity ($\sqrt{\sigma_V\sigma_W} \geq 1.80$ m/s) was also observed at Station A-2, which now is a consequence of the turbulence generated by wind over the more complex topography in the region of Station A-2 than near Station A-6.
- Extremely low diffusion conditions ($\sqrt{\sigma_V\sigma_W} < 0.20$ m/s) do not occur at all at either location in the summer, or at Station A-6 in the fall.
- Extremely high diffusion conditions do not show a preferred season.
- The diffusivity (in terms of $\sqrt{\sigma_V\sigma_W}$) typically ranges from 0.2 to 1.4 m/s, with most values concentrated between 0.2 to 0.4 at Station A-2 and between 0.4 and 0.6 at Station A-6.

The approach shown does not require inference of low altitude diffusion from temperature lapse rate data, a dubious process in the very rugged terrain of the area, but rather it gives quantitative measurements of actual diffusion. Using generally accepted boundary layer formulas and measured lapse rate data from the rawinsonde soundings, these values can often be extrapolated upward to allow estimation of conditions at levels above the 30-m towers.

4. CONCLUSIONS

The analyses performed to date on the regular meteorological data and on the results of the two special diffusion experiments have characterized diffusion conditions in the area of the two tracts as having the following main elements:

TABLE III-5

DIFFUSIVITY FREQUENCY DISTRIBUTIONS

Relative frequency distributions (%) of $\sqrt{\sigma_v \sigma_w}$ at Stations A-2 and A-6 in spring, summer, fall and winter. All measurements were made 20 m above the surface. All hours of the day are included.

Station A-2

Qtr \ $\sqrt{\sigma_v \sigma_w}$ *	.00	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	>2.0	Total # of Obs.
Spring	4	25	17	17	14	10	7	4	2	1	0	0	997
Summer	0	27	18	15	15	10	5	6	3	1	0	0	811
Fall	11	35	21	14	10	7	2	0	1	0	0	0	1283
Winter	1	71	14	8	5	2	0	0	0	0	0	0	570

Station A-6

Qtr \ $\sqrt{\sigma_v \sigma_w}$ *	.00	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	>2.0	Total # of Obs.
Spring	2	13	24	16	18	13	11	3	0	0	0	0	1165
Summer	0	15	33	19	17	11	5	1	0	0	0	0	1803
Fall	0	14	32	25	14	9	4	2	1	0	0	0	860
Winter	1	80	16	2	1	<1	0	0	0	0	0	0	1487

* Each interval of $\sqrt{\sigma_v \sigma_w}$ spans 0.20 m/s and commences with the value shown.

Conditions adverse to mixing occur most frequently in winter and least frequently in summer.

In such adverse conditions (low winds, low inversion heights), the dispersion in the sheltered large canyons of Tract U-a is significantly poorer than in the more open, rolling country of Tract U-b.

Standard diffusion formulas appear to be applicable for the modeling of plume diffusion aloft if the turbulence is properly defined, preferably by actual measurement.

The surface temperature measurements at Stations A-2, A-4, and A-6 provide a satisfactory description of lower level temperature lapse rates.

5. WORK SCHEDULED

Analysis of turbulence data collected continuously by the sensors on the tracts will continue throughout the second year to corroborate the first year's measurements. No further special diffusion experiments are planned.

As was mentioned in the meteorology section, rawinsonde soundings will be terminated after January 31, 1976. Continued data on lapse rates in the bottom 150 m of the atmosphere will be available from the surface temperature measurements at Stations A-2, A-4, and A-6, as discussed previously. No further special experiments to measure turbulence or diffusion aloft are planned.

C. AIR QUALITY

Until recently, ambient-air quality has not been monitored within the Uinta Basin region. The closest monitoring has been conducted by the Colorado Department of Health who have been using high-volume samplers to monitor particulate matter in northwestern Colorado. Data from selected Colorado stations for 1973 are given in Table III-6. The station nearest to the tracts is at Rangely, approximately 32 km (20 mi) northeast of the tracts. The particulate levels for that station are not representative of an area similar to that of the tracts, because the station is in an area of more human activity and higher levels of transportation and industry. Gaseous pollutant information is almost nonexistent for even northwestern Colorado.

TABLE III-6

SUSPENDED PARTICULATE DATA
NORTHWESTERN COLORADO-1973
(MICROGRAMS PER CUBIC METER)

Station	Annual Arithmetic Mean	Annual Geometric Mean	High Value Recorded	Low Value Recorded
Rangely	36	31	168	6
Fruita	71	62	167	2
Grand Junction	103	93	255	35
Palisade	37	32	89	11
Meeker	67	56	227	3
Rio Blanco	20	14	144	3

SOURCE: Colorado Air Pollution Control Division, 1975.

The present ambient-air quality in the study region is considered good because the region contains few anthropogenic sources of air contaminants. This is because the air quality is governed almost exclusively by air masses that enter the area over long distances of essentially source-free countryside, with little contribution from local sources. Some exceptions are areas around the small town of Bonanza, 6 km (4 mi) north of the tracts, where gilsonite mining and crushing and truck traffic contribute to the particulate loading, and areas along unpaved roadways that are sources of fugitive dust and automotive emissions. Various oil fields in the area are also expected to contribute to air contamination by causing higher than background levels of hydrocarbons. Other sources of air contamination are Vernal, Utah, about 64 km (40 mi) northwest of the tracts, and Grand Junction, Colorado, 104 km (65 mi) southeast of the tracts.

1. GASEOUS POLLUTANTS

a. Objectives

The air quality baseline monitoring program is being conducted to define the existing air quality in and around Tracts U-a and U-b as a reference, or baseline, against which to compare conditions in the future when development of the oil shale mining and processing facilities has taken place. This comparison will enable a quantitative assessment of the actual environmental impact of these developments. An additional objective of the program is the identification of existing conditions that might be near any applicable standards for air quality, and thus to identify constituents for which any increase in ambient concentrations would exceed existing Federal and/or State standards.

b. Methodology

Air quality was measured during the baseline year at eight comprehensively instrumented monitoring stations and from a site near Station A-9. Figure III-19 shows the locations of the monitoring stations and the parameters monitored at each.

The scope of measurement was extensive, especially in view of the small area being covered (about 104 km^2 (40 sq mi)); the absence of any population (Bonanza, Utah, with a population of 30, about 6 km (4 mi) further north, is the only

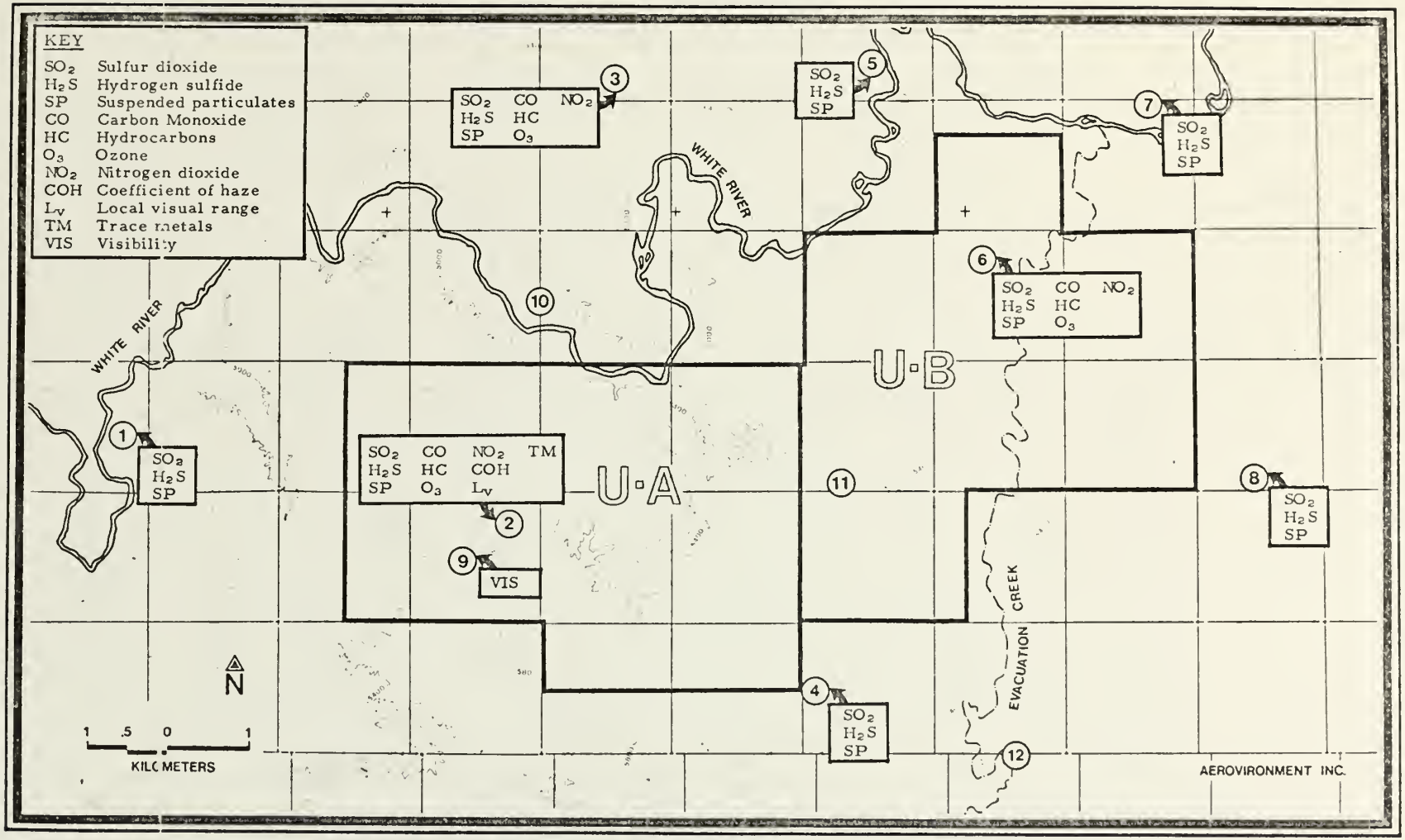

FIGURE III-19. LOCATIONS OF AIR QUALITY MEASUREMENT STATIONS ON TRACTS U-a AND U-b.

inhabited location); and the lack of any sources that would contribute to spatial variability from station to station. This density of one station per 13 km^2 (5 sq mi) compares with the approximately one station per 155 km^2 (60 sq mi) in the heavily populated, emission-source filled Los Angeles area.

Stations A-1 through A-8 consisted of a trailer that housed the air quality monitoring instrumentation and recording equipment and contained air conditioning, heating, and a back-up propane-fueled electric generator that automatically activated if the primary power source failed. These generators provided the primary electrical power from February to April 1975, when commercial electrical power was installed in seven of the trailers. Station A-5 is still powered by a second external propane-fueled generator; aesthetic considerations precluded construction of a power line to its location.

Each of the eight stations had certain instruments in common. All of them were equipped with a digital data-logging system with a punched paper tape recorder and a multipoint strip chart recorder for backup. At each of these stations, sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) were monitored continuously by flame photometric detection, with a gas chromatographic column isolating SO_2 and H_2S.

Three of the stations (A-2, A-3, and A-6) contained additional equipment for the continuous measurement of carbon monoxide (CO), hydrocarbons (HC), ozone (O_3), and nitrogen oxides (NO_x). CO and HC were both measured by flame ionization detection, with gas chromatographic separation of methane from total hydrocarbons allowing the computation of non-methane hydrocarbons (NMHC), and catalytic conversion of CO to methane giving detection of CO. Ozone was monitored by chemiluminescence with ethylene. Nitrogen oxides were measured by chemiluminescence of NO with ozone, catalytic conversion of NO_x to NO for similar chemiluminiscent measurement, and subtraction of NO from NO_x to give nitrogen dioxide (NO_2).

Each of the major air quality instruments were calibrated quarterly and after each malfunction by secondary calibration standards (permeation tubes and compressed gas mixtures) on site. The secondary standards were in turn calibrated quarterly by EPA-prescribed wet chemical analysis procedures (Chapter I, Title 40, Code of Federal Regulations, Part 53).

To assist the reader in interpreting the data to be presented, Table III-7 shows the reasonably estimated accuracy of the major air pollutant instruments and methods used.

TABLE III-7

ESTIMATED RMS ACCURACY OF MAJOR AIR QUALITY MEASUREMENTS

Component	Calibration Accuracy (1)	System (1) Accuracy(2)	Total Accuracy (1)
SO_2	± 5% or 2 ppb	± 5% or 3 ppb	±7% or 4 ppb (11 $\mu g/m^3$)
H_2S	± 10% or 5 ppb	± 6% or 6 ppb	±12% or 8 ppb (11 $\mu g/m^3$)
Suspended Particulates	--	± 1 $\mu g/m^3$	±1 $\mu g/m^3$
O_3	± 5% or 0.01 ppm	± 2% or 0.005 ppm	±5 % or 0.01 ppm (20 $\mu g/m^3$)
NO, NO_x	± 5% or 0.01 ppm	± 3% of 0.01 ppm	±6% or 0.01 ppm (20 $\mu g/m^3$)
NO_2 (3)	--	± 4% or 0.01 ppm	±6% or 0.02 ppm (40 $\mu g/m^3$)
THC, CH_4	± 2% or 0.1 ppm	± 2% or 0.1 ppm	±3% or 0.1 ppm (65 $\mu g/m^3$)
NMHC (4)	± 2% or 0.1 ppm	± 3% or 0.1 ppm	±4% or 0.2 ppm (135 $\mu g/m^3$)

Notes:

(1) The larger of the values given applies.

(2) Total for all portions, including installation, recorder, and readout.

(3) Including subtraction of NO from NO_x during data reduction

(4) Including subtraction of CH_4 from THC during data reduction

c. Summary of Results

For reference in the ensuing discussion, Table III-8 gives the U.S. Ambient Air Quality Standards (AAQS) for the various gaseous pollutants monitored on the tracts. There are no Utah state air quality standards for gaseous pollutants. There are no standards, either state or federal, for H_2S; a reference for interpreting the data is the California 1-hour standard of 42 $\mu g/m^3$ (.03 ppm).

Some of the results presented differ slightly from results reported in the quarterly reports. The quarterly results were based on preliminary analysis of the data available at that time; the results presented here can be considered final for data collected from November 1974 through October 1975, with calculations based on later data possibly still subject to minor adjustment. Also, many of the prior reports summarized data for a quarter by analyzing only the central month of that quarter. In this report all of the data collected are used for summaries, unless otherwise noted.

With respect to gaseous pollutants, the air quality in the two-tract area has been exceptionally good, which is expected because of their remote location. All pollutants were present at measurable quantities in the beginning of the monitoring program when well-drilling and set-up activities were carried out by various participating groups. As the program settled down to normal baseline monitoring, most of the pollutant concentrations dropped to the threshold limits of the instruments. The gaseous pollutants that still showed variations and were measurable included ozone and nonmethane hydrocarbons (NMHC). Both of these pollutants were observed occasionally at levels exceeding the AAQS.

It was not uncommon for the 6 A.M. to 9 A.M. NMHC standard of 160 $\mu g/m^3$ to be exceeded, and three-hour averages of twice the standard were often observed. Table III-9 presents the highest 6 A.M. to 9 A.M. NMHC readings at Stations A-2, A-3, and A-6 for each of the last four quarters. This table shows that the peak reading at each station, except at Station A-2 in spring, is several times the federal standard; however, it should be noted that the federal standard for NMHC of 160 $\mu g/m^3$ (0.24 ppm) for the 3-hour period from 6 A.M. to 9 A.M. was established to reduce the formation of photochemical pollutants (for which separate standards exist also) and not as a health standard per se. Since the NMHC standard is often exceeded in unpopulated areas throughout the United States, the levels on the tracts are not unusual.

TABLE III-8

FEDERAL AIR QUALITY STANDARDS FOR GASEOUS POLLUTANTS

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Ozone (O_3)	1 hour	160 $\mu g/m^3$ (0.08 ppm)	same as primary
Carbon Monoxide (CO)	8 hours	10 mg/m^3 (9 ppm)	same as primary
	1 hour	40 mg/m^3 (35 ppm)	same as primary
Sulfur Dioxide (SO_2)	Annual Average	80 $\mu g/m^3$ (0.03 ppm)	-
	24 hour	365 $\mu g/m^3$ (0.14 ppm)	-
	3 hour	-	1300 $\mu g/m^3$ (0.5 ppm)
Nitrogen Dioxide (NO_2)	Annual Average	100 $\mu g/m^3$ (0.05 ppm)	same as primary
Hydrocarbons (corrected for methane) (NMHC)	3 hour (6-9 a.m.)	160 $\mu g/m^3$ (0.24 ppm)	same as primary

SOURCE: National Primary and Secondary Ambient Air Quality Standards - Federal Register, Vol. 36, Numbers 84, Washington, D.C., April 30, 1971.

TABLE III-9

PEAK 0600 to 0900 MST NMHC READINGS ($\mu g/m^3$) at STATIONS A-2, A-3, and A-6

	A-2	A-3	A-6
Winter	1110	630	1210
Spring	100	*	1400
Summer	480	1970	390
Fall	630	1460	280

*No data was collected in that quarter due to an instrument problem.

Carbon monoxide, a common pollutant in urban areas, was almost non-existent on the tracts. The highest hourly average reading and the highest 8-hour average were 5.2 mg/m^3 and 3.9 mg/m^3, respectively, at Station A-3 in January 1975, when tract activities were at their peak. These peak readings were well below the federal 1-hour standard of 40 mg/m^3 or the 8-hour standard of 10 mg/m^3. No spatial, diurnal, or seasonal variations were observed in the CO levels, and readings were generally near the global background of around 0.3 mg/m^3.

Federal standards for NO_2 are written in terms of an annual average of 100 $\mu g/m^3$. Annual averages of NO_2 at Stations A-2, A-3, and A-6 were 10, 5, and 5 $\mu g/m^3$, respectively, which are very small compared with the standard. Nitrogen dioxide readings were higher in the early parts of the program because of tract activities and because air quality stations were powered by propane-burning electric generators. Even then, most of the observed readings were below 25 $\mu g/m^3$. Many readings between 25 and 50 $\mu g/m^3$ were recorded at Station A-6 during the summer, possibly because of its proximity to roads, which enabled curious tourists to visit the sites. Except for these values, nitrogen dioxide readings did not seem to vary with location, season, or time of day.

The ozone values on the tracts were comparably lower than those observed in most U.S. cities, but were not as low as might have been expected. A diurnal trend was discernible, with ozone values peaking every day around 1500-1600 MST and dropping to a minimum of around 0600-0700 MST in the morning. This diurnal trend is seen in Figure III-20, which also shows that ozone readings varied with season, with higher values recorded from May through August. During the past year, federal standards were exceeded 42 times at Station A-2; standards were not exceeded at Stations A-3 and A-6*. The highest recorded reading was 190 $\mu g/m^3$ at Station A-2 in the spring. The peak hour and average hourly values of ozone and the number of observations exceeding standards at each site for each season are tabulated in Table III-10.

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* These numbers differ from previously reported values because of a calibration error in early O_3 data, discovered during an internal data audit. The actual values decreased only slightly, but since many of the high values were just over the standard, the small decrease in O_3 levels resulted in a large decrease in instances where standards were exceeded.

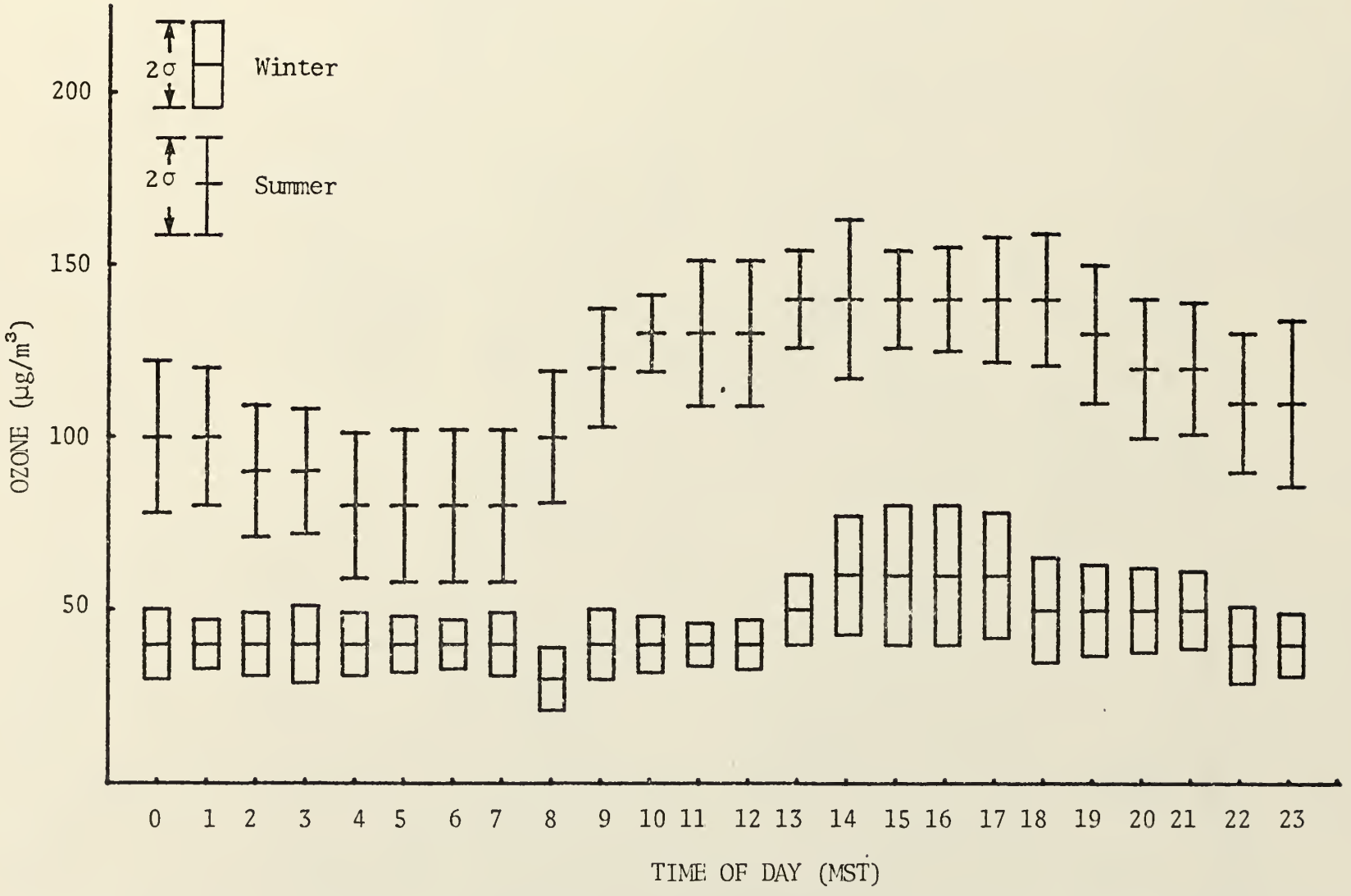


FIGURE III-20. DIURNAL VARIATIONS IN MEAN OZONE CONCENTRATIONS WITH THEIR STANDARD DEVIATIONS AT STATION A-2 IN WINTER AND SUMMER.
Data is based on the Central Month of Each Quarter.

TABLE III-10

PEAK AND AVERAGE HOURLY VALUES OF OZONE ($\mu g/m^3$).

Station	Quarter	Peak Hour	Average	Number of Obs	No of hrs Excdng Stds
A-2	Winter	120	40	820	0
	Spring	190	110	1017	14
	Summer	180	110	1749	28
	Fall	130	60	2141	0
A-3	Winter	130	70	2082	0
	Spring	150	90	1733	0
	Summer	140	70	1813	0
	Fall	140	80	1305	0
A-6	Winter	150	80	945	0
	Spring	150	80	1841	0
	Summer	130	80	2034	0
	Fall	140	60	2085	0

Both H_2S and SO_2 were monitored at eight locations on the tracts. There is no record of any federal SO_2 standards being exceeded. There are no federal standards for H_2S.

Relatively high values of H_2S (25-50 $\mu g/m^3$) were recorded at Stations A-2, A-3, A-4, A-6, and A-7 during the early months of the program, but the values had dropped to the instrument threshold of about 7 $\mu g/m^3$ after the spring. During the winter and spring of 1974-75, Station A-7, which is just east of Bonanza, was averaging higher H_2S and SO_2 readings than the other monitoring stations. Before June the average readings there were about 15 $\mu g/m^3$ of SO_2 and 20 $\mu g/m^3$ of H_2S; after that the levels there matched those at the other stations. The higher readings of both H_2S and SO_2 before the summer can be attributed to well-drilling and other activities on the tracts.

With the exception of Station A-7, SO_2 levels have generally been below the instrument response threshold of 13 $\mu g/m^3$ throughout the first year. The average value for all stations combined was about 5 $\mu g/m^3$, well below the instrument threshold. Thus, SO_2 and H_2S are not present in ambient air on the tracts except in the vicinity of open wells.

To summarize air pollution for the first year the highest and average values for all gaseous pollutants--except for O_3, which was treated separately in Table III-10--at Stations A-1 through A-8 for each season are given in Table III-11. Table III-12 presents peak SO_2 readings for time averages for which standards exist. Relative frequency distributions of concentrations of SO_2, H_2S, CO, NO_2, and O_3 for each season at either Station A-2 or A-6 are given in Table III-13. Since station-to-station variability has been slight, data presented in this table are representative of the general air quality on Tracts U-a and U-b. The relationship between the observed values and the short-term ambient air quality standards for CO, O_3, and SO_2 is also shown in Table III-13, which again demonstrates the high quality of the air in the study area.

d. Conclusions

Overall, the air quality on Tracts U-a and U-b has been typical of any arid, uninhabited region. The levels of most of the gaseous contaminants (NO_2, SO_2, H_2S, CO, NMHC) were all typical of background concentrations and, with the exception of NMHC, were insignificant compared with the levels of ambient air quality standards. The sulfur compound concentrations were generally almost undetectable by

TABLE III-11

COMPARISON OF THE HIGH HOUR AND AVERAGE VALUES
SO_2, H_2S, CO, AND NO_2
AT STATIONS A-I TO A-8 THROUGHOUT THE YEAR

Station	High Hour				Average Values				
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	
A-1	*	5	15	15	*	0	0	0	
A-2	15	25	20	10	5	0	5	0	
A-3	10	15	10	15	5	0	5	5	
A-4	0	5	5	20	0	0	0	0	
A-5	20	40	20	10	5	5	5	0	SO_2 ($\mu g/m^3$)
A-6	10	10	20	10	5	0	5	0	
A-7	30	45	45	10	10	15	5	5	
A-8	15	10	15	25	5	5	5	5	
A-1	*	15	10	10	*	5	0	0	
A-2	50	70	5	10	20	10	0	0	
A-3	30	30	5	10	5	10	5	0	
A-4	25	35	15	25	15	15	5	0	
A-5	5	5	10	15	0	0	0	0	H_2S ($\mu g/m^3$)
A-6	20	30	30	5	5	15	10	0	
A-7	40	45	15	5	20	20	0	0	
A-8	10	10	5	15	5	0	0	0	
A-2	3.0	1.8	.5	.6	.4	.1	.1	.1	
A-3	5.2	*	1.4	1.2	1.7	*	0.3	0.3	CO (mg/m^3)
A-6	3.0	0.8	*	1.2	0.4	0	*	.3	
A-2	80	190	20	40	10	20	0	0	
A-3	40	30	0	10	10	10	0	0	NO_2 ($\mu g/m^3$)
A-6	20*	20	100	100	0	0	20	0	

* Insufficient data collected for meaningful statistical analysis.

TABLE III-12

PEAK 3-HOUR, 24-HOUR AND ANNUAL AVERAGES
OF SO_2 ($\mu g/m^3$) AT STATIONS A-1 THROUGH A-8
FOR EACH OF THE LAST FOUR QUARTERS

Station	Peak 3-Hour Average				Peak 24-Hour Average				Annual
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Average
A1	*	5	10	15	*	5	5	10	0
A2	15	25	10	10	10	15	10	5	5
A3	10	10	10	10	10	10	10	10	5
A4	0	5	5	10	0	5	0	0	0
A5	20	35	20	10	15	15	10	5	5
A6	10	10	10	5	5	5	10	5	5
A7	30	25	40	10	20	20	25	5	10
A8	10	10	10	20	5	5	10	5	5

TABLE III-13

RELATIVE FREQUENCY DISTRIBUTIONS (%) OF CONCENTRATIONS OF CO, O_3, NO_2 AT STATION A-2 AND SO_2 AND H_2S AT STATION A-6 IN WINTER, SPRING, SUMMER, AND FALL
Values To The Right Of The Double Line Exceed A Short-Term Federal Ambient Air Quality Standard

	Conc / Qtr	0-1.9	2.0-3.9	4.0-5.9	6.0-10.0	>10	Station
CO (mg/m^3)	Winter	>99	<1	0	0	0	A-2
	Spring	100	0	0	0	0	
	Summer	100	0	0	0	0	
	Fall	100	0	0	0	0	
	Conc / Qtr	0-59	60-99	100-129	130-160	161-200	
O_3 ($\mu g/m^3$)	Winter	87	12	1	0	0	A-2
	Spring	5	31	50	12	2	
	Summer	4	34	33	25	4	
	Fall	46	49	5	0	0	
	Conc / Qtr	0-24	25-49	60-74	75-100	>100	
NO_2 ($\mu g/m^3$)	Winter	79	17	4	0	0	A-2
	Spring	76	17	4	2	1	
	Summer	100	0	0	0	0	
	Fall	98	2	0	0	0	
	Conc / Qtr	0-12	13-22	23-32	32-42	> 42	
H_2S ($\mu g/m^3$)	Winter	95	5	0	0	0	A-6
	Spring	48	48	4	0	0	
	Summer	48	37	15	0	0	
	Fall	100	0	0	0	0	
	Conc / Qtr	0-15	16-30	31-100	100-365	365	
SO_2 ($\mu g/m^3$)	Winter	100	0	0	0	0	A-6
	Spring	100	0	0	0	0	
	Summer	> 99	<1	0	0	0	
	Fall	100	0	0	0	0	

the instrumentation used. The NMHC concentrations occasionally exceeded ambient air quality standards but were still in the range of normal background levels.

Ozone was the only constituent observed at significant levels. Levels were slightly above the global background but still normal most of the time; however, there were instances of high ozone concentrations that exceeded the ambient air quality standards, which is not typical of such areas but not unusual either.

e. Work Scheduled

Air-quality monitoring during the second year will continue as in the first year. The main objective will be verification of the representativeness of the first-year data.

Because the air quality on the tracts is so uniform and the concentrations of most of the pollutants are so low, verification will require less intensive monitoring. Approved for termination in mid-January 1976 were any further measurements with the AISI tape sampler at Station A-2 (which never read above the neglibible value of 0.003 COH/ft and usually read 0.000 COH/ft). Approval to decrease the number of monitoring stations and thereby reduce the energy consumption, cost, and environmental impact of the baseline program has also been proposed. These modifications include all the air quality measurements at Stations A-1, A-2 (except the integrating nephelometer), A-3 (except O_3), A-4, A-5, and A-8.

2. PARTICULATES AND TRACE METALS

a. Objectives

Refer to Section III.C.1.a for a discussion of program objectives.

b. Methodology

Air-quality monitoring instruments for particulates are at Stations A-1 through A-8. Suspended particulate matter was collected for 24 hours every sixth day, simultaneously, at all of the stations by high-volume samplers with constant flow controllers. After appropriate conditioning, the filters

from the samplers were weighed at the field laboratory before and after sample collection to obtain the mass concentration of particulate matter below about 25 μm in size.

Station A-2 contained several additional instruments for measuring particulates and their impact on visibility. An AISI tape sampler monitored the coefficent of haze (COH), an index of soiling. An integrating nephelometer measured the scattering of light by particulate matter and computed a measure of the local clarity of the atmosphere (L_V, local visual range).

In addition to collection by the high-volume sampler, samples of particulate matter were also collected at Station A-2 by a Lundgren impactor that separated particulates into three size ranges (.10 to .65 μm, .65 to 3.6 μm, and 3.6 to 20.0 μm diameter) and then collected the particles for subsequent analysis for trace metals and certain other elements. Samples were collected for 15 days each month. The collected samples were analyzed by the ion-excited X-ray emission technique using the cyclotron at the University of California at Davis. The analysis yielded measurements of the mass concentrations of all of the elements in the periodic table. Sensitivities were a few nanograms per cubic meter (ng/m^3) for sodium and above, and a microgram per cubic meter for lighter elements.

Delivery of the multi-day impactor from the manufacturer took almost 14 months; this impactor will be used in the second-year of environmental baseline monitoring. In the interim an indentical instrument was loaned to the project for February through May 1975. Trace elements were analyzed from June through December 1975 on one high-volume filter per month from Station A-2 by a combination of emission spectroscopy, atomic absorption, and wet chemical analysis. This kind of analysis is not as sensitive as the ion-excited X-ray emission technique, however.

c. Summary of Results

Table III-14 gives the annual and quarterly geometric means, standard geometric deviations, and maximum and minimum of particulate concentrations in micrograms per cubic meter at all sites in the last four quarters. Because particulate concentrations have usually been lognormally distributed, the geometric mean presented can be considered to correspond to the maximum concentration expected at a 50 percent frequency.

Data indicate that particulate concentrations on the tracts vary by season and by spatial variation. Concentrations were

TABLE III-14

PARTICULATE CONCENTRATIONS-QUARTERLY GEOMETRIC MEANS, STANDARD GEOMETRIC DEVIATIONS, AND MAXIMUM, MINIMUM, AND ANNUAL GEOMETRIC MEANS ($\mu g/m^3$)

Station	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
Geo. Mean								
Winter	9.1	8.1	9.4	7.8	11.5	*	8.2	7.2
Spring	11.5	11.1	12.1	14.0	21.0	17.2	10.5	21.8
Summer	17.4	11.7	15.9	22.6	41.8	39.2	17.4	23.4
Fall	9.5	10.7	11.3	17.2	31.2	17.2	11.1	18.6
Std. Geo. Dev.								
Winter	1.3	1.5	1.3	1.5	1.4	*	1.3	1.4
Spring	1.7	1.9	2.1	1.8	1.7	1.9	2.1	1.8
Summer	2.1	2.7	1.6	1.4	1.9	1.4	1.4	1.5
Fall	1.8	2.0	1.8	1.8	2.3	2.1	1.7	2.0
Maximum								
Winter	14.5	26.8	15.6	15.9	19.8	*	13.9	12.4
Spring	29.1	41.7	49.9	44.5	49.5	52.0	46.7	48.4
Summer	48.9	41.4	38.3	57.1	91.8	74.7	31.6	36.8
Fall	31.1	29.6	29.2	47.1	127.4	52.8	26.8	49.7
Minimum								
Winter	4.0	3.3	6.5	4.6	5.3	*	5.9	5.3
Spring	4.6	3.9	4.3	6.0	8.7	6.9	2.6	8.0
Summer	4.0	2.0	5.8	15.3	6.4	23.2	7.9	12.5
Fall	4.6	3.3	5.2	4.0	8.6	4.9	3.9	7.9
Ann Geo Mean	10.8	10.0	10.7	13.0	22.2	15.5	11.3	15.4

* Sampler malfunction; insufficient data for meaningful statistical analysis.

lowest during winter because the snow cover on the ground kept dust and fine soil particles from entering the atmosphere by wind and vehicle activity. In contrast, particulate concentrations were highest in summer.

The geometric mean ranged from 9 $\mu g/m^3$ at Station A-1 in winter to 42 $\mu g/m^3$ at Station A-5 in summer. The highest concentration observed was 127 $\mu g/m^3$ at Station A-5 in the fall and the lowest concentration of 3.3 $\mu g/m^3$ was recorded at Station A-2 in winter. Station A-5, located on the west bank of the White River and about 200 m west of the main dirt road linking Bonanza and the tracts, recorded the highest particulate levels in general, with Stations A-6, A-8, and A-4 following in increasing order of cleanliness. All of the dirtier locations were near the more traveled unpaved roads in the area.

None of the recorded values exceeded federal or state standards, which are presented in Table III-15. The most stringent short-term standard is the National Secondary Standard, which sets the upper limit at 150 $\mu g/m^3$ average over 24 hours; this is not to be exceeded more than once a year.

Several times between January 29 and May 13, 1975, size-fractionated particulate samples were collected at Station A-2 by a multistage Lundgren impactor. The particulates were analyzed for trace elements using ion-excited X-ray emission techniques.

Table III-16 shows the elements detected during these sampling periods. Most of the elements, with the exception of normal soil constituents, were found at concentrations of less than or around 10 ng/m^3, with most of the mass generally found in the smaller size fractions. The elements that existed in larger quantities were Si, S, K, Ca, Ti, Mn, and Fe. The considerable increase in Si concentrations from March to May and the increasing numbers of larger particle sizes indicated a natural soil-derived aerosol, which increased in concentration as the weather became warmer and dryer. Concentrations of typical anthropogenic aerosols such as S, Cu, Zn, and the automotive-derived aerosols Br and Pb were very low, only a small percentage of typical urban values. The concentrations of these anthropogenic aerosols were lower in April and May than in previous months, reflecting a drop in project activities and increased ventilation associated with spring. For example, relatively large amounts of lead in the size range of 0.10-0.65 μm were detected January 29 (470 ng/m^3) and February 3 (631 ng/m^3), which reflected the impact of vehicular activities and drilling associated with the exploration program, which was at its peak.

From June through October, particulates collected by the high-volume sampler at Station A-2 were analyzed for trace metals. X-ray emission techniques could not be used on these filters.

TABLE III-15

AMBIENT AIR QUALITY STANDARDS FOR PARTICULATE MATTER
($\mu g/m^3$)

Pollutant	Averaging Time	National Standard(1)	
		Primary	Secondary
Suspended Particulate Matter	Annual Geometric Mean	75	60
	24 hour	260	150

(1) National Primary and Secondary Ambient Air Quality Standards-Federal Register, Vol. 36, Number 84, Washington, D.C., April 30, 1971.
Note: The State of Utah has adopted the Federal Particulate standards (Utah Air Conservation Regulations as revised July 9, 1975, State of Utah, Department of Social Services, Division of Health)

TABLE III-16

TRACE ELEMENTS DETECTED AT STATION A-2 USING ION-EXCITED X-RAY EMISSIONS TECHNIQUE

ANY ELEMENTS NOT SHOWN HAVE NOT BEEN DETECTED

Sampling Record	Sensitivity of Analysis	Size (μm) Range	Li	Be	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Zr	Ba	Pt	Au	Hg	Pb
1/29-2/11	5 μC	3.6-20.0	-	-	B	B	★	C	A	B	B	B	A	A	A	A	B	A	A	A	-	-	★	-	-	-	B	-	-	-	A
		.65-3.6	-	-	B	A	A	D	C	★	A	B	A	A	A	A	B	A	A	A	-	-	★	-	-	-	A	A	-	-	B
		.10-.65	-	-	C	B	B	D	D	C	C	B	★	B	B	B	B	A	B	B	C	-	B	-	-	-	B	B	B	-	D
2/17-3/8	50 μC	3.6-20.0	-	-	A	-	A	B	B	★	A	A	A	★	-	A	B	★	A	A	★	-	A	-	A	-	★	A	★	-	A
		.65-3.6	A	★	A	-	A	B	B	★	A	A	A	★	-	A	B	-	A	A	-	★	★	-	★	★	★	★	★	★	A
		.10-.65	-	-	B	-	B	C	C	★	B	B	★	★	-	A	B	★	A	A	-	★	A	★	-	-	★	★	★	★	B
4/4-4/19	50 μC	3.6-20.0	-	-	A	A	B	D	A	A	B	B	B	A	-	A	B	-	A	A	-	-	★	-	-	-	★	-	-	-	A
		.65-3.6	-	-	A	A	B	D	C	★	B	B	A	★	-	A	B	-	A	A	-	-	★	-	-	A	★	-	-	-	A
		.10-.65	-	-	A	-	A	C	C	★	A	B	A	A	-	★	B	-	★	A	-	-	A	-	-	-	★	-	-	-	A
5/1-5/13	50 μC	3.6-20.0	-	A	A	A	B	C	A	★	A	B	★	A	-	A	A	-	★	★	-	-	A	-	-	-	★	-	-	-	★
		.65-3.6	-	-	A	A	B	B	B	★	A	A	★	★	A	A	A	-	A	★	-	-	A	-	-	-	★	-	-	-	A
		.10-.65	-	-	B	C	C	D	D	☆	C	D	B	A	-	A	D	-	★	A	-	-	A	-	-	-	★	-	-	-	A

- Element not found

★ Concentration < detection limit

A 10 ng/m^3 > concentration > 0 ng/m^3

B 50 ng/m^3 > concentration > 10 ng/m^3

C 100 ng/m^3 > concentration > 50 ng/m^3

D 500 ng/m^3 > concentration > 100 ng/m^3

Atomic absorption was used instead to identify Li, Na, K, Se, and Hg; turbidimetric wet analysis, to detect S; titrimetric wet analysis for Cl and Br; colorimetric analysis, for As; and emission spectrography, for all the other elements. Particulate sizes collected ranged from under 0.1 μm to above 25 μm. Thus, much larger particles than those collected by the multiday impactor were present. Because of this and because different techniques other than X-ray emissions were used, the results were somewhat different from those given in Table III-16.

As shown in Table III-17, in the same format as Table III-16, the elements Al, Cl, Ca, and Zn were detected with concentrations of hundreds of nanograms per cubic meter (ng/m^3). The sizes of the particles containing these elements are probably greater than the 20-μm cutoff of the Lundgren impactor, since their concentrations were usually lower than 50 ng/m^3 when X-ray emission techniques were used. Concentrations of all elements were higher than in winter and spring because of the higher particulate loading in the atmosphere; however, concentrations of most of the elements were still less than 50 ng/m^3 . Analysis for silicon could not be performed because Si is a major constituent of glass fiber filters on which the samples were collected. All of the analyses were corrected for trace amounts of other filter elements.

When trace-element levels in the air over Tracts U-a and U-b were compared with concentrations of the same elements collected over the Atlantic Ocean and in Antarctica (as reported by Duce et al. 1975), Al, Fe, Mn, Cu, and Pb concentrations collected at the tracts were generally in the background range typical of locations extremely isolated from man-made pollution or surface dust; the levels of Cr, V, Zn, and Se were well above corresponding background levels. The background level of Pb indicated the tracts' air to be free of the impact of gasoline burning (except for the brief periods mentioned previously), thus confirming that the air arriving over the study area did not reflect contamination from upwind, although remote, urban areas.

d. Conclusions

Particulate concentrations were typical. Winter concentrations were very low and summer concentrations were about twice the winter concentrations, reflecting the aridness of the area. The high silica content of the particulates and the extremely low background level of lead concentrations indicated that the suspended particulates were almost entirely composed of soil. The impact of anthropogenic combustion was negligible.

TABLE III-17

TRACE ELEMENTS ON HIGH VOLUME SAMPLER FILTERS
COLLECTED AT STATION A-2 BETWEEN 6/11/75 AND 10/9/75

Sampling Date	Li	Be	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Zr	Ba	Pt	Au	Hg	Pb
6/11/75	*	A	B	B	C	NA	B	E	A	D	B	B	-	A	B	B	-	D	A	*	*	A	B	A	C	-	*	*	B
7/1/75	A	A	B	A	D	NA	A	D	A	D	A	B	-	-	-	-	-	C	A	B	*	*	A	*	-	-	-	*	B
8/10/75	A	A	B	B	D	NA	A	D	A	D	A	C	C	B	B	B	B	D	A	B	*	*	B	A	B	-	*	*	B
9/15/75	A	A	B	B	E	NA	A	D	A	E	B	D	D	B	B	B	B	D	A	*	*	A	B	A	B	-	A	*	B
10/9/75	A	A	B	B	D	NA	A	E	*	D	-	B	B	B	B	B	B	D	A	B	*	A	B	A	-	-	A	*	A

- Element not found
* Concentration < detection limit
A 10 ng/m^3 > concentration > 0 ng/m^3
B 50 ng/m^3 > concentration > 10 ng/m^3
C 100 ng/m^3 > concentration > 50 ng/m^3
D 500 ng/m^3 > concentration > 100 ng/m^3
E > 500 ng/m^3
NA Not Analyzed

e. Work Scheduled

Refer to Section III.C.1.e for a description of the work scheduled and for the proposed program modifications.

3. VISIBILITY

a. Objectives

Refer to Section III.C.1.a for a discussion of program objectives.

b. Methodology

Documentation of the visibility of the study area was an important aspect of the baseline air quality program. Two sets of measurements were used. To define the local air clarity on the tracts, the integrating nephelometer was installed on Station A-2. To record the regional visibility in terms of the ability to see remote vistas from the area of the tracts, photographs were taken of the entire unobstructed panorama once every 30 days from an elevated location near Station A-9. The photographs were taken with monochromatic and color film at three different times of the day; and photographs of standard charts for color, gray scale, and resolution were included in each sequence.

c. Summary of Results

Figure III-21 is a series of photographs of typical views from the visibility photo site above Station A-9. Photographs were taken every 45 degrees from west to southeast. The 90-degree segment, including the southern and southwestern directions, is blocked by nearby high terrain. Although also blocked by terrain, the direction due north of the cameras was used for photographing an identification sign that also contained standard resolution, color, and gray scales (the resolution chart is missing on the photo in Figure III-21). These standard charts were used as controls for printing the photographs, which served as the permanent visibility record.

The integrating nephelometer gave an average scattering coefficient of $0.06 \times 10^{-3}m^{-1}$ during the past year, which corresponds to a local visual range (assuming a 2 percent contrast threshold for the eye) of 79 km (49 mi). The highest scattering (lowest visual range) recorded was $b_s = 0.10 \times 10^{-3}m^{-1}$, which corresponds to 47 km (29 mi), while the most clear hour showed $b_s = 0.02 \times 10^{-3}m^{-1}$. The most clear hours were observed in the winter when snow covered the ground. The value of $0.02 \times 10^{-3}m^{-1}$ is of clarity comparable to that of particle-free air. All observed values have corresponded to extremely clear, background-quality air.

A diurnal variation in the scattering coefficient was observed in all seasons except summer, with the night and early morning hours showing about 15 percent more scattering (lower visibility) than did the afternoon and evening hours. This diurnal effect shows that fine-scale particulates (of natural or anthropogenic origin) collect near the ground during the stable, calm night hours and are mixed into the atmosphere during the better ventilated hours and that the increased human activity and winds on the tract during the day do not stir up enough dust to counteract this stability.

During the hour the photographs in Figure III-21 were taken, the scattering coefficient was $0.06 \times 10^{-3}m^{-1}$ and the local visual range was 79 km (49 mi). As the photos show, this visual range could not be observed in some sectors because clouds remote from the tract obscured terrain at such distances. However, the view to the northeast does show Blue Mountain at 60 km (37 mi). In general, the photographically derived visibilities and those computed from the integrating nephelometer measurements correlate well, indicating that the Uinta Basin air mass is relatively homogenous and that the localized nephelometer measurements are representative of a large area.

d. Conclusions

Visibilities also fit into the same pattern as the other components of air quality. The air clarity in winter was almost totally particle-free air. Although summer visibility was not quite as great, which corresponds with the higher particulate concentrations then, it was still at typical background levels.

a. West

b. Northwest

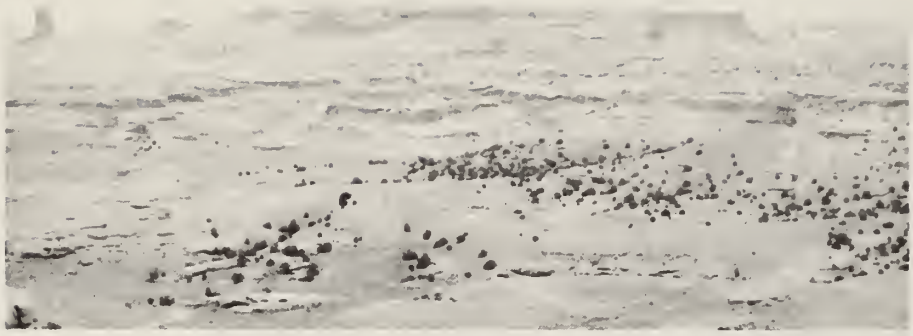
FIGURE III-21 PHOTGRAPHIC VISIBILITY RECORD

Photgraphic visibility record for 1400 on 11 April 1975. The weather on this day was overcast and clouds obscured very remote terrain. The photographs are spaced at 45° intervals around the horizon, and the field of view of each is about 35°.

c. North. Identification sign and control charts. Camera is focused on sign, so terrain is out of focus.

d. Northeast.

FIGURE III-21, (Cont'd) Note hazy appearance of distant Blue Mountain (indicated by arrow), some 60 km to the northeast, because of moisture in the air.



e. East.

f. Southeast.

FIGURE III-21, (Cont'd) Clouds obscure portions of the Rabbit Hills (20 km to the east); the Cathedral Bluffs (50 km to the east) are not visible.

e. Work Scheduled

Refer to Section III.C.1.e for a description of the work scheduled and of proposed program modifications.

D. RADIOACTIVITY

Data on radioactivity levels in the region of the tracts prior to the monitoring program appeared to be non-existent.

1. OBJECTIVES

Many sections of Utah and Colorado are underlain by radioactive ores. The ores provide a source of uranium for the nation and in some cases, as in Grand Junction, Colorado, constitute an environmental problem. Radiation in the air over the tracts was measured to satisfy two objectives. First, measuring the baseline level of radioisotopes now in atmospheric particulate matter established whether there was radioactive material on the surface that could be carried aloft by the wind, and established a baseline level against which to compare future levels after the surface has been disturbed by mining. Second, determining radioactivity in the oil shale itself, a portion of which will eventually be laid on the surface after retorting, helped determine how wind-blown particles from the shale could change existing radioactivity conditions.

2. METHODOLOGY

Ambient radiation was continuously monitored throughout the tracts by a variety of radiation-measuring instruments, including a pressurized ion chamber, a portable ionization chamber survey meter and a sodium iodide crystal scintillation counter, and thermoluminescent dosimeters. The pressurized ion chamber was rotated from site to site at intervals of six days. Before each installation of the pressurized ion chamber, the portable ionization chamber and the scintillation counter were used to survey the area to determine that the continuous measurements would be representative of the area. After June 1975, three thermoluminescent dosimeters were installed at each of the 12 monitoring stations and were read monthly to determine overall average radiation dosage levels.

Radioactivity was monitored monthly by gross alpha and beta measurement and by a qualitative gamma radiation scan of one high-volume filter sample from Station A-2 and one from Station A-6. In addition, one sample of air, collected in December 1974, was analyzed for radon-222 activity.

3. SUMMARY OF RESULTS

The pressurized ionization chamber showed exposure rates varying from 8 to 30 μR/hr, depending on the site location and the season. Localized sources in the vicinity of the monitoring sites have indicated values of up to about 60 μR/hr, still well within the background range. The late summer values tended to be slightly higher than those observed earlier. Average radioactivity levels measured by thermoluminescent dosimetry at all 12 stations are consistent with the ionization chamber data, with monthly average values generally in the range of 10-15 μR/hr.

Analyses of filter samples of particulate matter collected at Stations A-2 and A-6 showed all radioactive isotype activities to be in the background range throughout the year. The alpha and the beta levels have both decreased significantly during the first year of monitoring. Alpha activity decreased continuously from about 0.3 pCi/m^3 in January to 0.03 pCi/m^3 in October and beta activity decreased from 0.06 pCi/m^3 in January to 0.005 pCi/m^3 in October. This decay by about a factor of 10 occurred at both Stations A-2 and A-6, and it is uncorrelated with the particulate mass concentration, which generally increased during the same period. At the same locations, qualitative gamma scans showed the presence of Ra^{226} and Bi^{214} at less than 0.7 pCi/m^3 during months of highest activity, with various other isotopes displaying significantly smaller activities.

Two air samples taken in December 1974 both showed a radon-222 activity of 0.64 pCi/1. According to the EPA National Environmental Research Center in Las Vegas, which analyzed these samples, values below 1.0 pCi/1 are considered normal background levels.

Analysis by the U. S. EPA of a single oil shale sample collected from Well X2 revealed a uranium concentration of less than 5 ppm, which is considered negligible. Specific activities in this sample, which was taken from a depth of 221 m (725 ft), show Ra^{226} = 1.6 pCi/g, U^{234} = 0.29 pCi/g, U^{235} = 0.011 pCi/g, U^{238} = 0.26 pCi/g, Th^{230} = 0.54 pCi/g, and Th^{232} = 0.31 pCi/g. Analyses of four surface-soil samples collected in December 1974 showed Ra^{226} activity at 0.17 to 0.87 pCi/g and activity of the man-made radioisotope Sr^{90} and 0.000 to 0.52

pCi/g. This level of radioactivity is also considered normal. The absence of significant radioactive materials in either the ore or the surface soil is consistent with the normal radiation levels observed in the air and in airborne particulates.

4. CONCLUSIONS

Based on the data acquired to date there appears to be no significant radioactivity either in the air above the tracts in the surface soil or in the oil shale underground. Thus, the current normal baseline radioactivity conditions should not change significantly when development begins.

5. WORK SCHEDULED

Based on the radiation levels observed, the Area Oil Shale Supervisor has approved termination of all radiation survey activities on January 31, 1976. Monitoring of background radiation will continue with the thermo-luminescent dosimeter network and with the monthly analyses of particulate matter for radioactivity.

E. SOUND LEVELS

There appears to be no data for ambient noise levels in the region of the tracts. The area is expected to be relatively quiet because of the lack of major noise sources, except in the vicinity of human activity (vehicle traffic, gilsonite mining, oil field operation, etc.). Wind, the White River, and other streams and wildlife are the primary natural sources of noise in the area.

1. OBJECTIVES

The objective of the sound-level baseline monitoring program was to determine the sound levels on the tract for each season of the year for use as a baseline against which to compare future sound levels.

2. METHODOLOGY

Sound-level surveys of the entire two-tract area were made at three different times between April 1975 and January 1976. Each survey consisted of measurements at various monitoring stations at different times of the day for several days. Measurements were not made before April 1975 because of the pervasive noise of the generators used to generate electricity for the monitoring stations during the first months of the program.

Measurements were made with a hand-held precision sound-level meter with A-scale (human aural response) filtering.

3. SUMMARY OF RESULTS

Sound level surveys in April and August 1975 and in January 1976 have consistently verified that in wind-free conditions the background sound level at various locations was 24-26 db(A), with air motion or insects as the main identifiable source of sound. Sites near the White River indicate around 30 db(A) with no wind, and the water identified as a source of sound. Increases in wind obviously cause higher sound levels, with 60 db(A) recorded at Station A-4 in a 5 m/s (11 mph) wind. No significant (> 2 db[A]) seasonal change in levels has been observed, although insects were readily identifiable as the main source of sound in quiet locations in August but not in the colder weather in April or January.

For reference, the threshold of hearing is 0 db(A), a quiet residential bedroom may be 25 to 30 db(A), and a quiet office may be 40 db(A). Forested or grassy regions typically show 40 to 50 db(A) in no-wind conditions. Thus, the sound environment on the tracts is very quiet because of the limited water, vegetation, and human and animal activities there.

4. CONCLUSIONS

The tracts are exceptionally quiet, except near the White River. The almost total absence of water or vegetation causes very little natural activity and therefore low sound levels. The lowest sound levels observed in all seasons were in the range 24 to 26 db(A).

5. WORK SCHEDULED

Because data from the sound-level measurement program has been extremely consistent from season to season, the Area Oil Shale Supervisor has authorized the cessation of sound-level measuring as of January 31, 1976.

GLOSSARY

adiabatic (lapse rate): the theoretical rate at which the temperature of the air decreases with altitude. It is 5.4°F per 1000 feet in dry air. If a theoretical parcel of air moves from a low altitude to a high one, and there is no exchange of heat with its environment, it becomes colder at the adiabatic lapse rate as the pressure on it decreases and allows it to expand.

aneroid barograph: an instrument which graphs a change in atmospheric pressure.

anthropogenic: related to or the result of the activities of man.

diffusivity: the quantity of a material passing through a given area per unit time.

diurnal: pertaining to meteorological actions, which are completed within 24 hours and which recur every 24 hours.

flux: the amount of some quantity flowing across a given area per unit time.

Gaussian plume: a plume that diffuses in the crosswind and vertical dimensions in a normal distribution and can be depicted by a bellshaped curve.

hygrometer: an instrument for giving a direct indication of the amount of moisture in the air, the indication usually being in terms of relative humidity.

inversion: a departure from the usual decrease or increase with altitude of the value of an atmospheric property, most commonly temperature.

isothermal: having constant temperature, at constant temperature.

mesoscale: locally occurring; intermediate level as opposed to macroscale and microscale.

rawinsonde: a method of upper-air observation consisting of an evaluation of the wind speed and direction, temperature, pressure, and relative humidity aloft by means of a balloon-borne radiosonde tracked by a radar direction finder.

shears: a line or narrow zone across which there is an abrupt change in the horizontal wind component parallel to this line.

Z: zulutime equal to Greenwich Mean Time.

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(June 1984)

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